Performance study for absorber type of the dual-readout calorimeter at the EIC

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On behalf of the korea Dual-readout Colorimeter team

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Dual-readout calorimeter

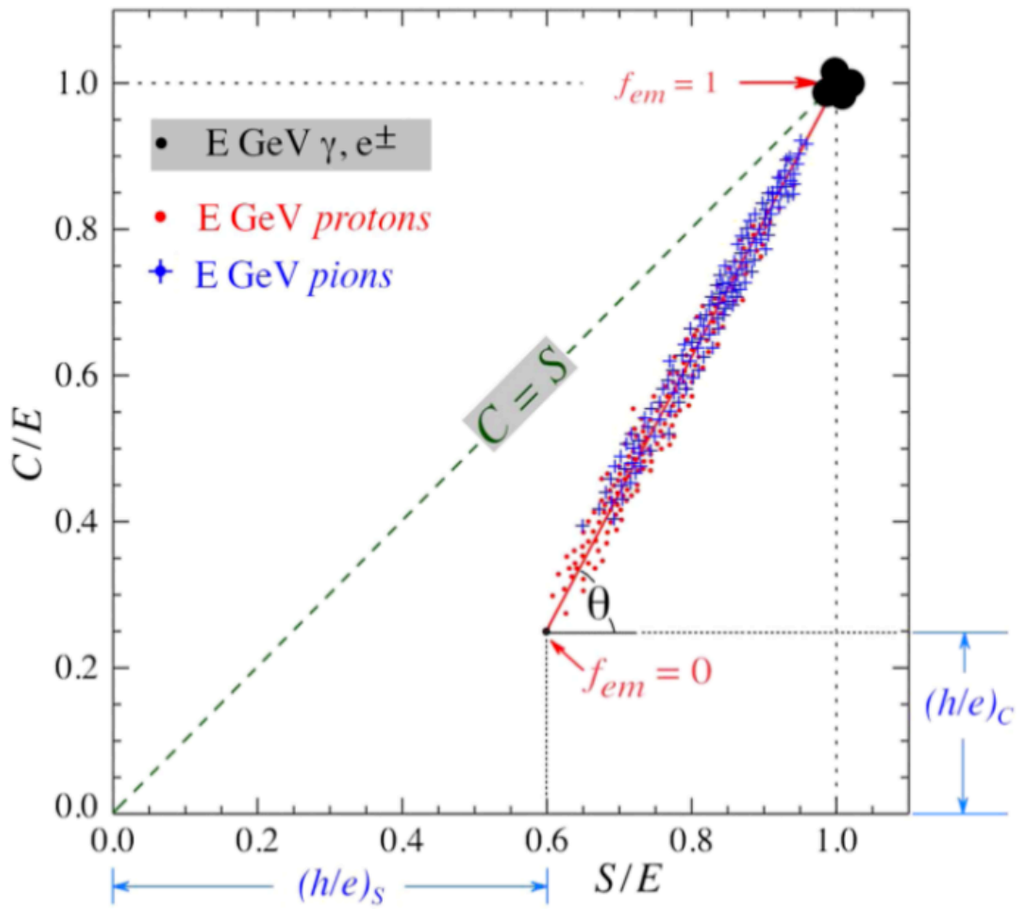
The dual-readout calorimetry

The major difficulty of measuring energy of hadronic Showers comes from the fluctuation of EM fraction of a shower, f_em

f_em can be measured by implementing two different Channels with different h/e response in a calorimeter

Dual-readout calorimeter may offer high-quality energy measurement for both EM particles and hadrons

Excellent energy resolution for hadrons can be achieved by Measuring f_em and correcting the measurement event-By-event



Energy measured from scintillation channel vs Čerenkov channel for EM particle, π & p

$$S = E[f_{em} + (\frac{h}{e})_S (1 - f_{em})],$$

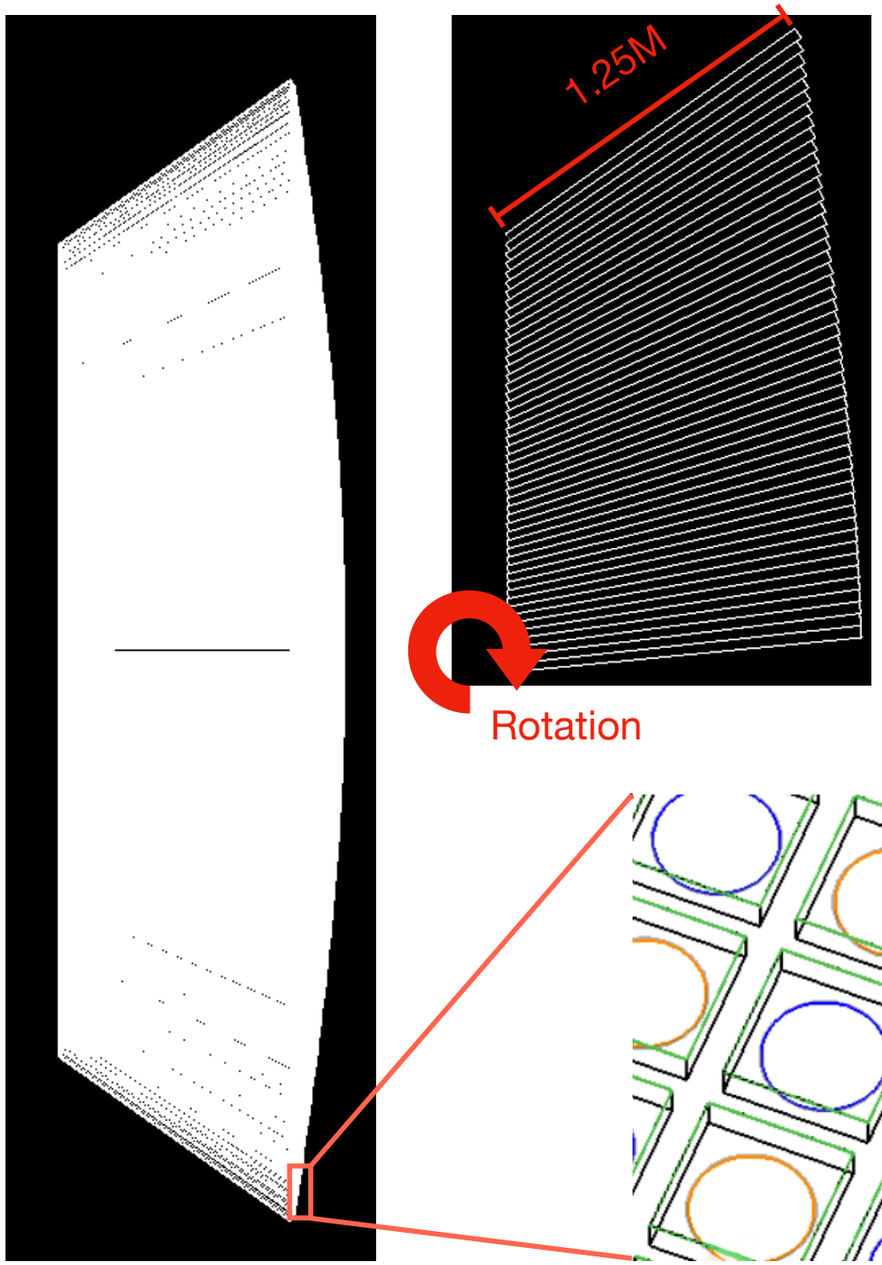
$$C = E[f_{em} + (\frac{h}{e})_C (1 - f_{em})]$$

$$\cot\theta = \frac{1-(h/e)_S}{1-(h/e)_C} \equiv \chi,$$

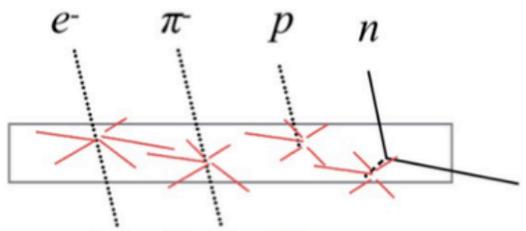
$$f_{em} = \frac{(h/e)_C - (C/S)(h/e)_S}{(C/S)[1-(h/e)_S] - [1-(h/e)_C]}$$

$$E = \frac{S - \chi C}{1 - \chi}$$

Geometry

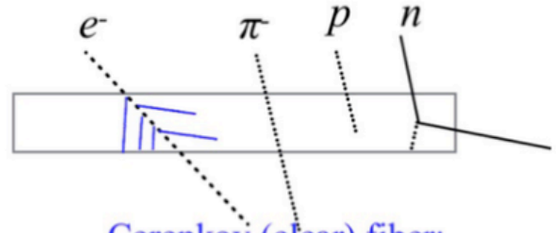


Signal generation: Scintillating & Cerenkov fibers

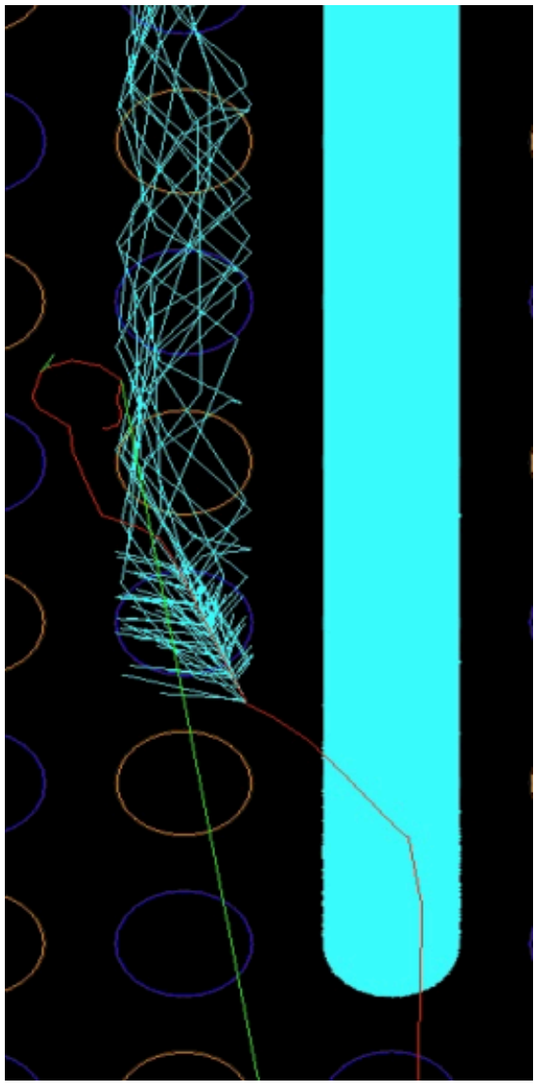


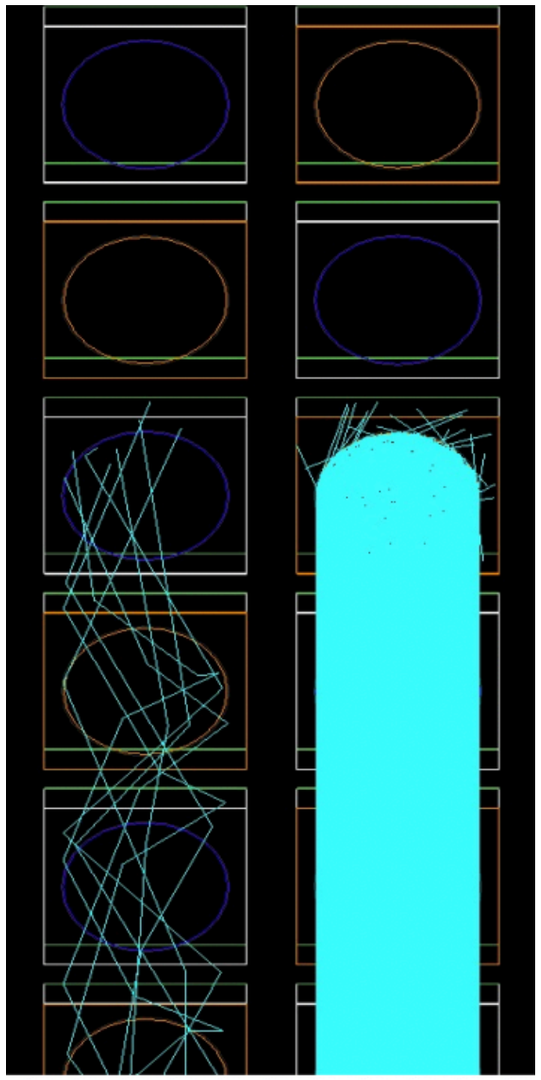
Scintillating fiber:
red light, random

Sci > Cer



Cerenkov (clear) fiber:
blue light, directional





The Geometry in this simulation

(FCC IDEA design) reduced height to 1.25m

Calibration with 20GeV e- in MC

Following variable are obtained as function of eta

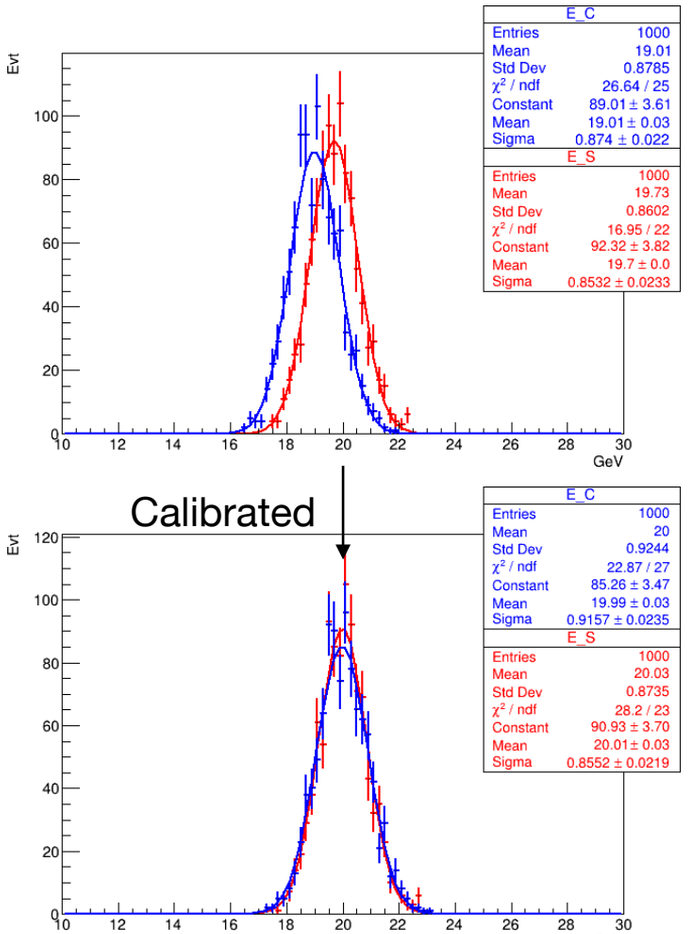
Energy deposit; # of photo-electron

of scintillation ch, cerenkov ch

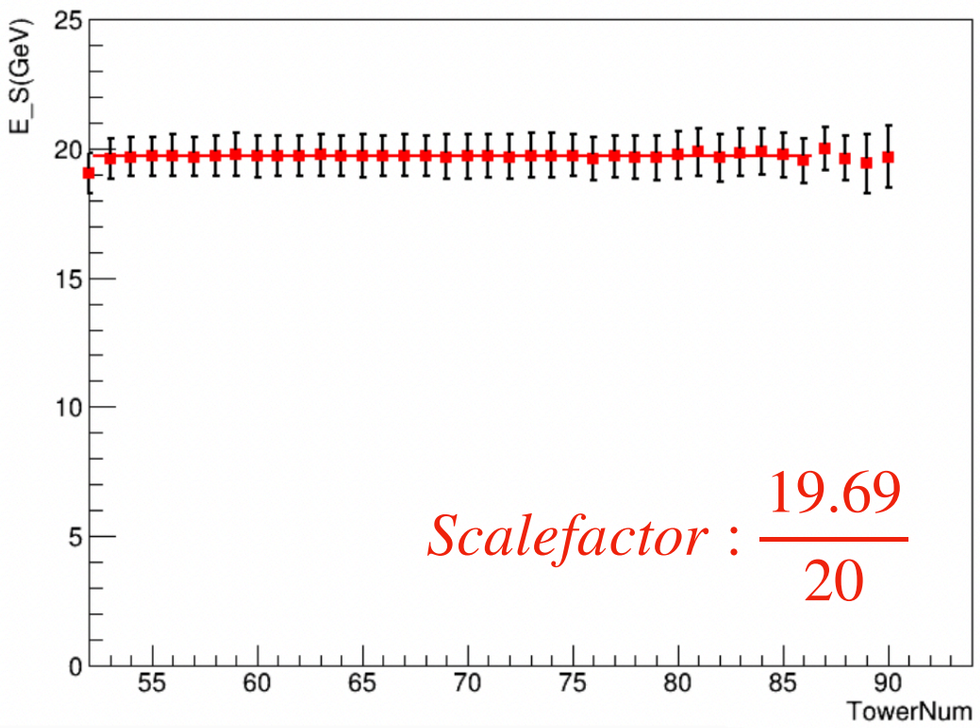
Energy is propotional to the number of photo-electrons

Simulation is used to obtain in the scale factors

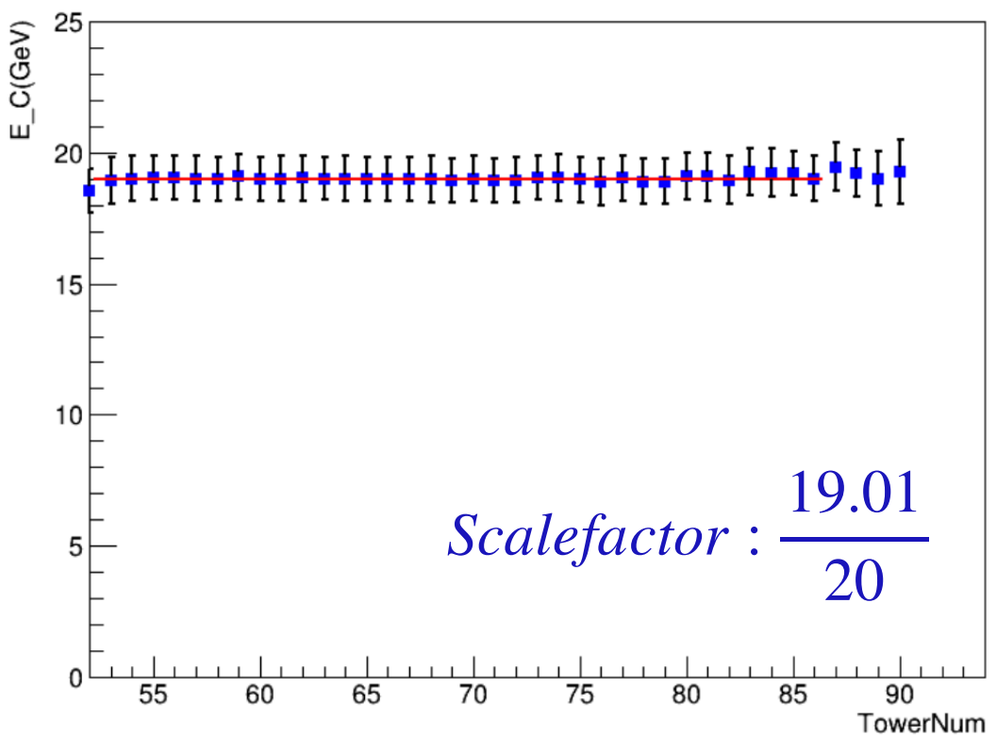
The scale factors used at measuring other energy or particle



Scintillation Channel Reconstructed



Cerenkov Channel Reconstructed



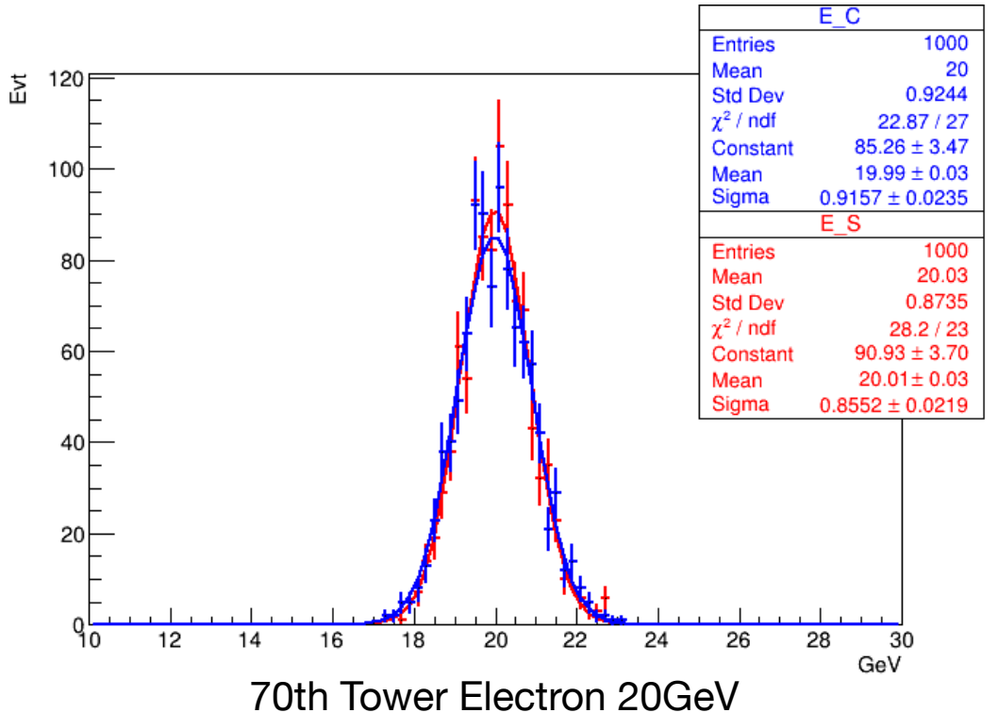
EM energy resolution

Calculated 6 different energy of e- beams

5, 20, 50, 70, 90, 110 GeV

FCC IDEA vs EIC ECCE

	Stochastic	Constant	Total, (at 20GeV)
2.5m (**IDEA**)	0.116	0.002	2.8%
1.25m **(ECCE)**	0.101	0.007	3%

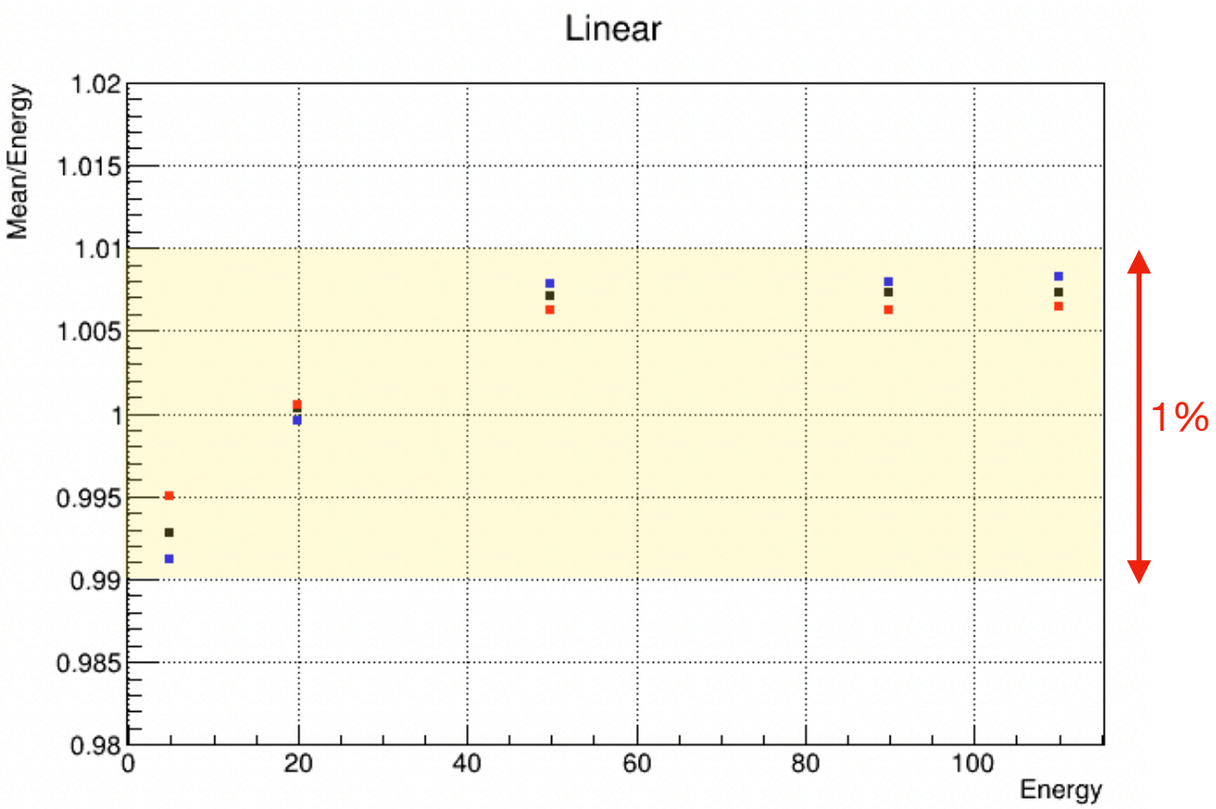


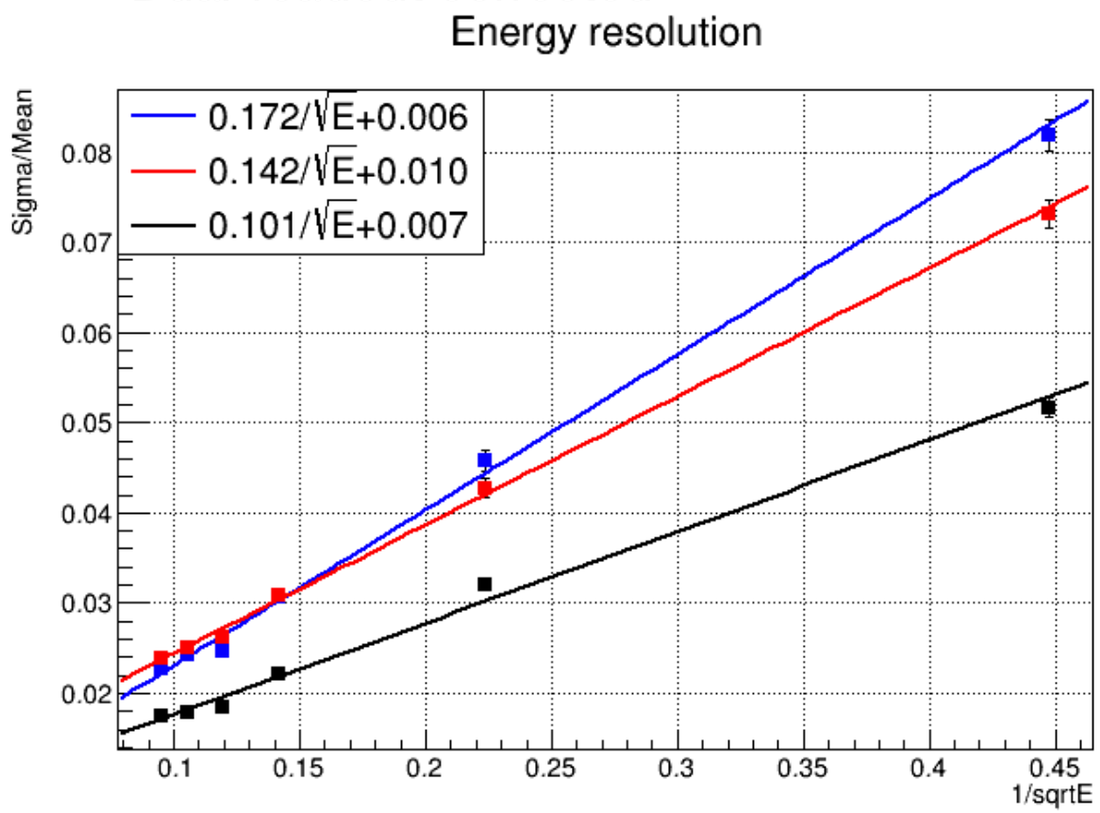
70th Tower Electron 20GeV

Cerenkov ch.

Scintillation ch.

Dual-readout corrected





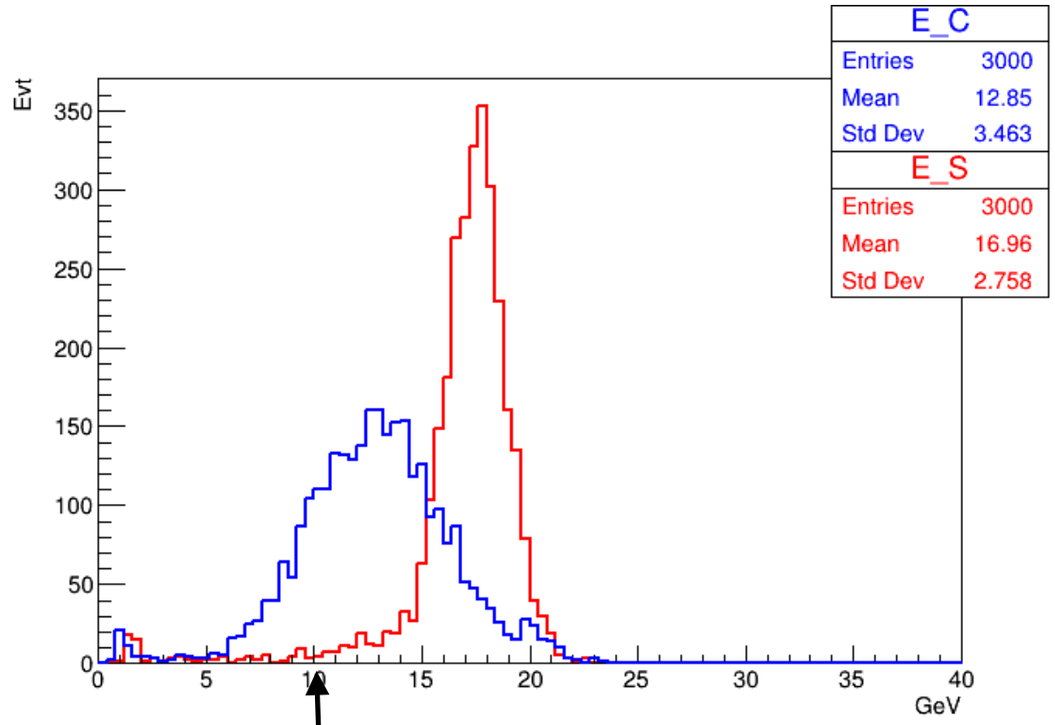
Simulation with single pion

Many leakages with Hadronic beams

It makes the left calls in the Gaussian distribution

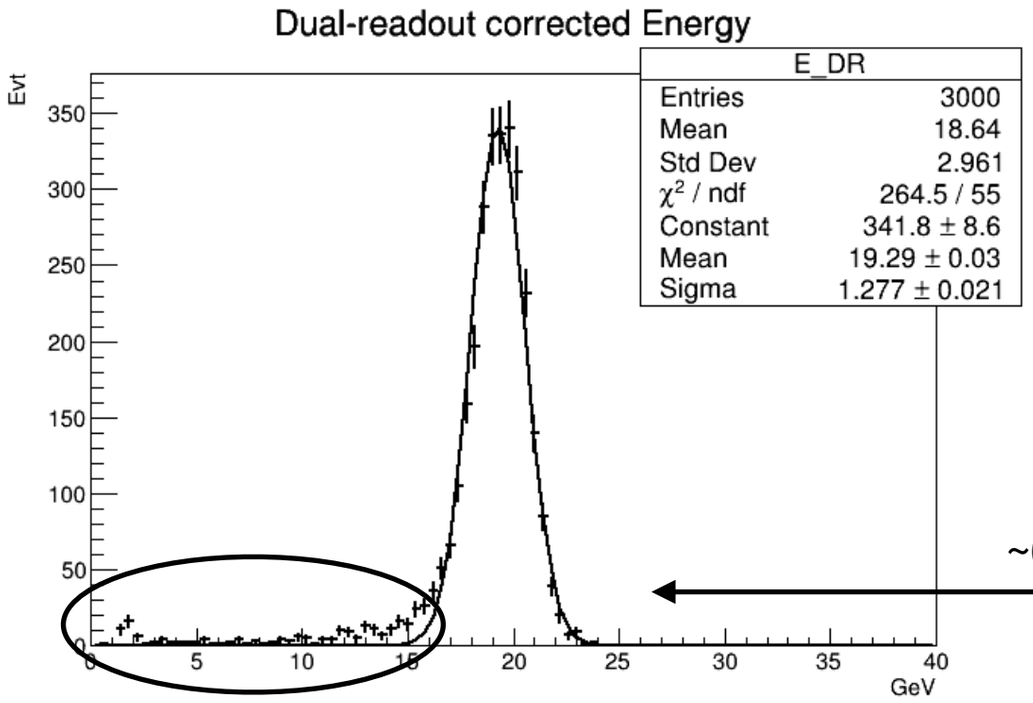
When 20GeV Pi+ beam, leakages ~6%

Higher Energy beam, more leakages

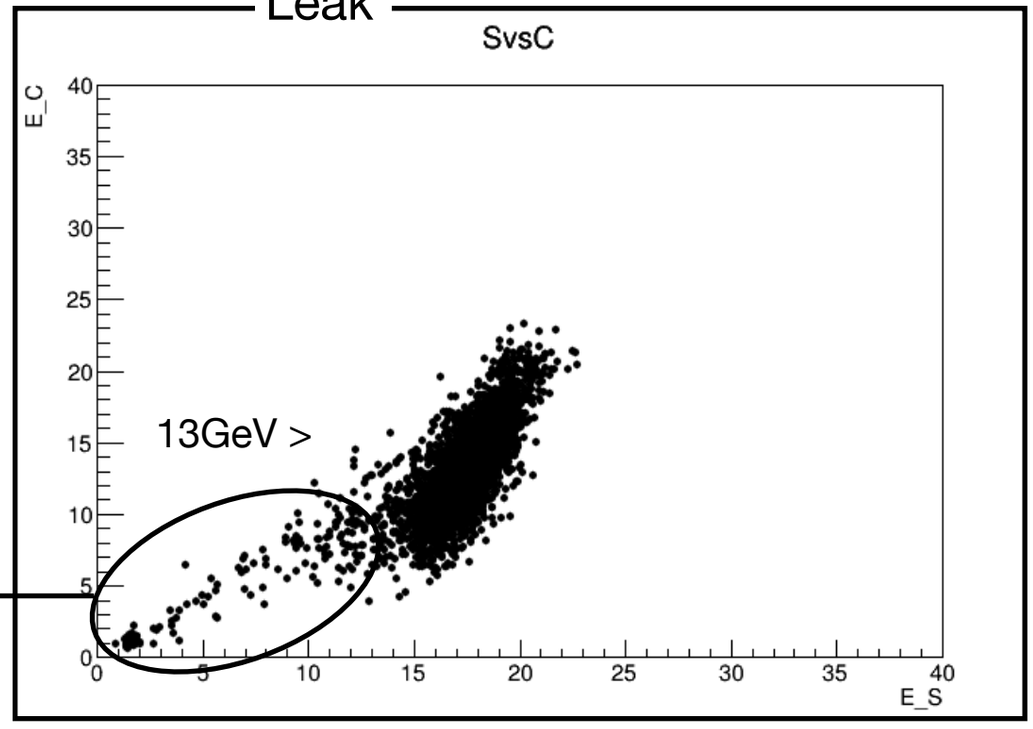


Leak

Pi+ 20GeV beam

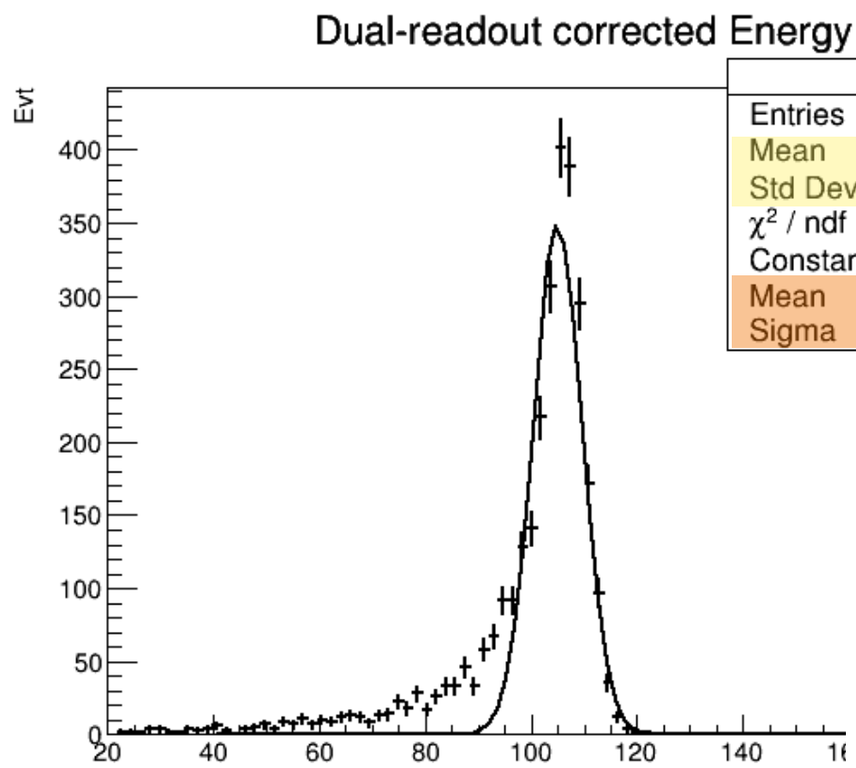


~6%



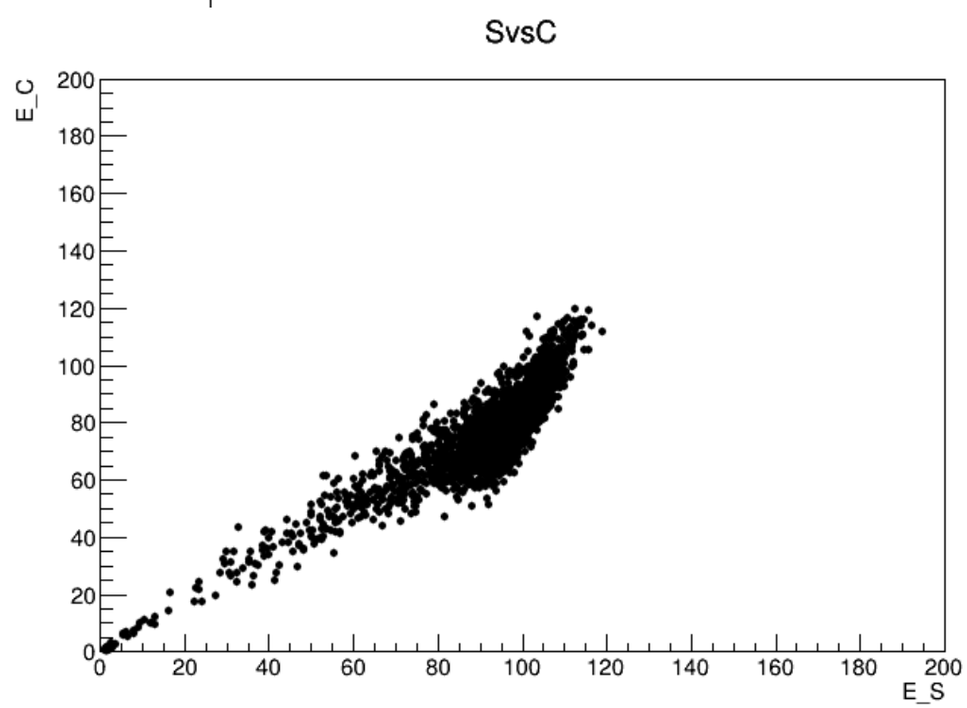
Hadronic Beam

Many leak with Hadronic beams



110GeV Pi+ beams

Leakage ~15%



Hadronic energy resolution

Measured in 6 different pi+ energy

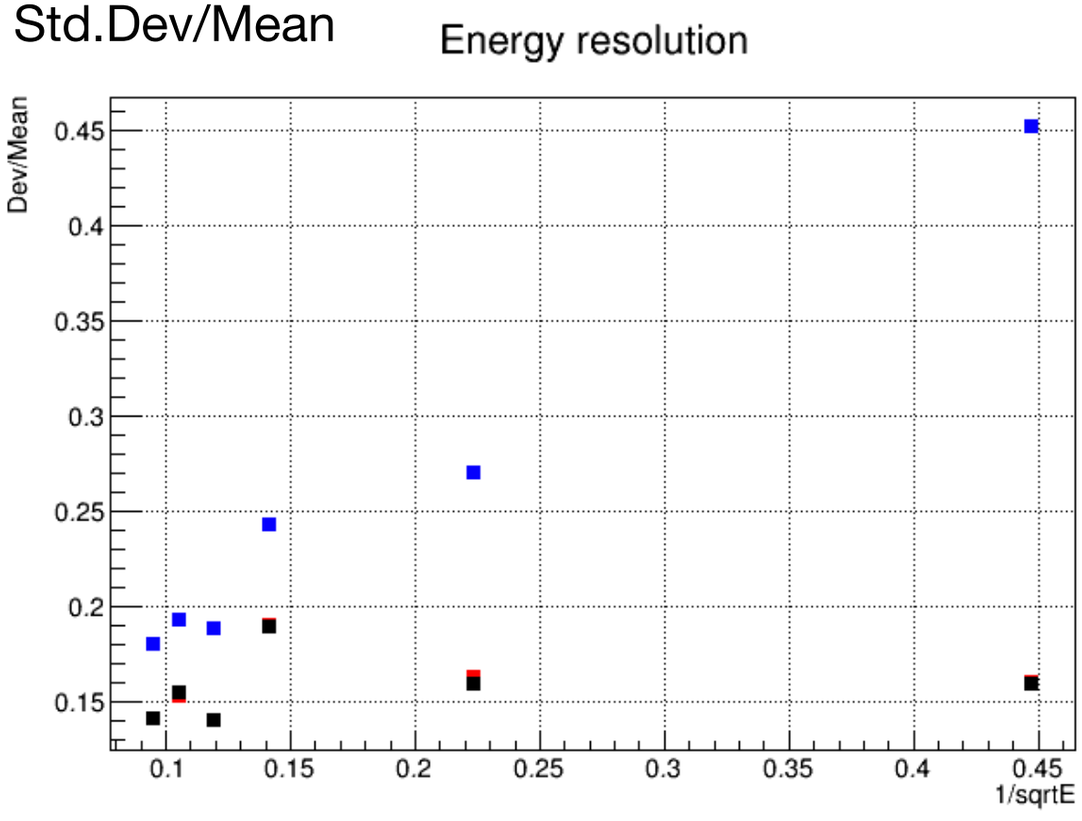
5, 20, 50, 70, 90, 110 GeV

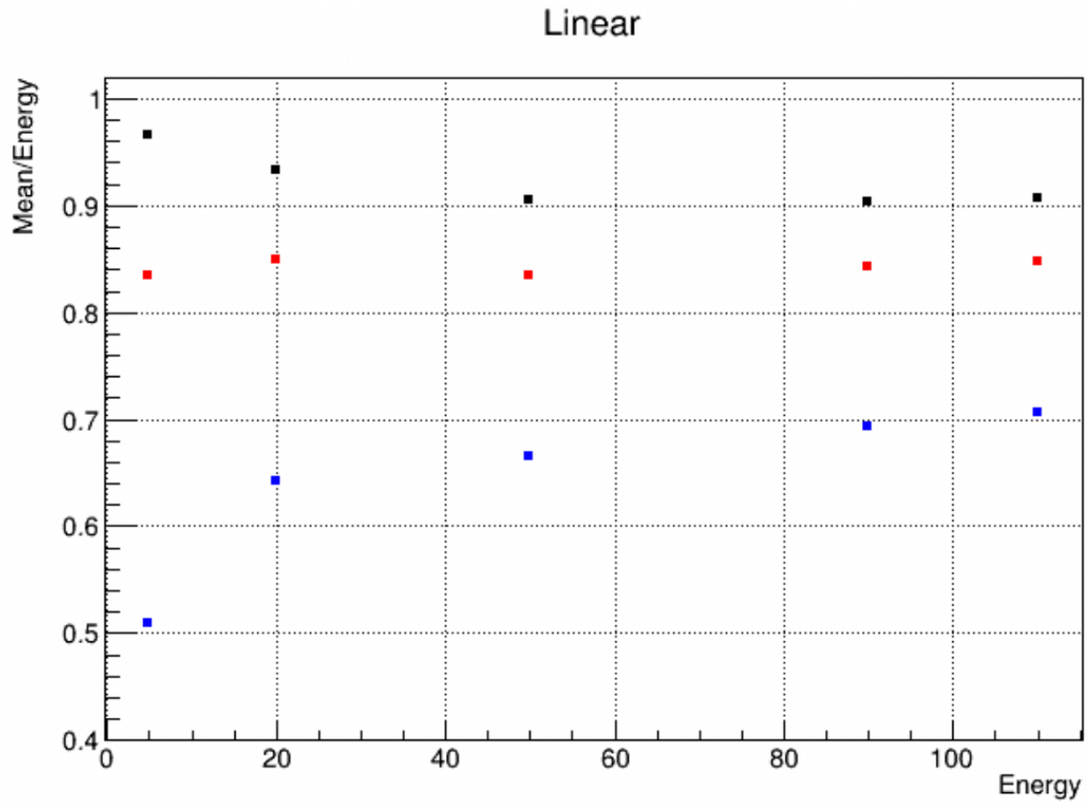
Dependence on sqrt{E} is off-linear

Cerenkov ch.

Scintillation ch.

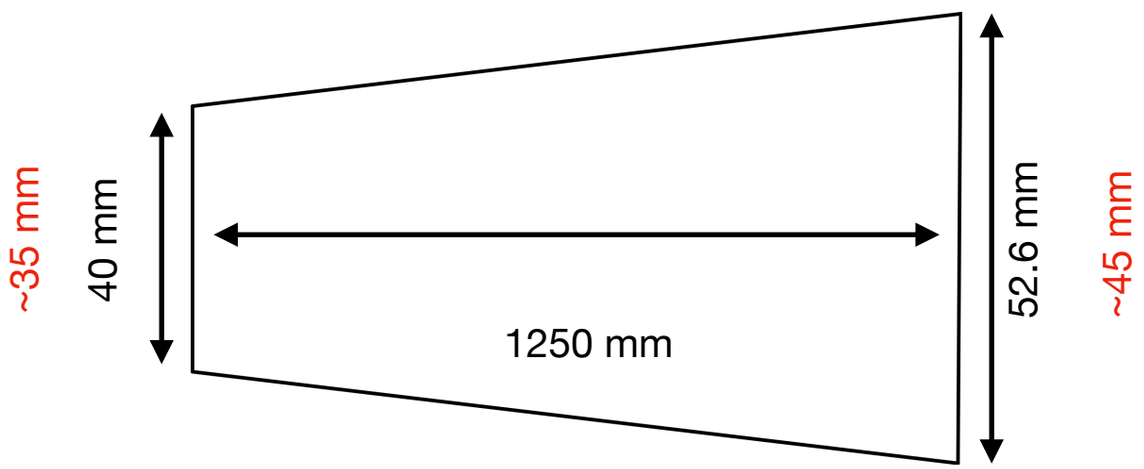
Dual-readout corrected





Tungsten as the alternative absorber

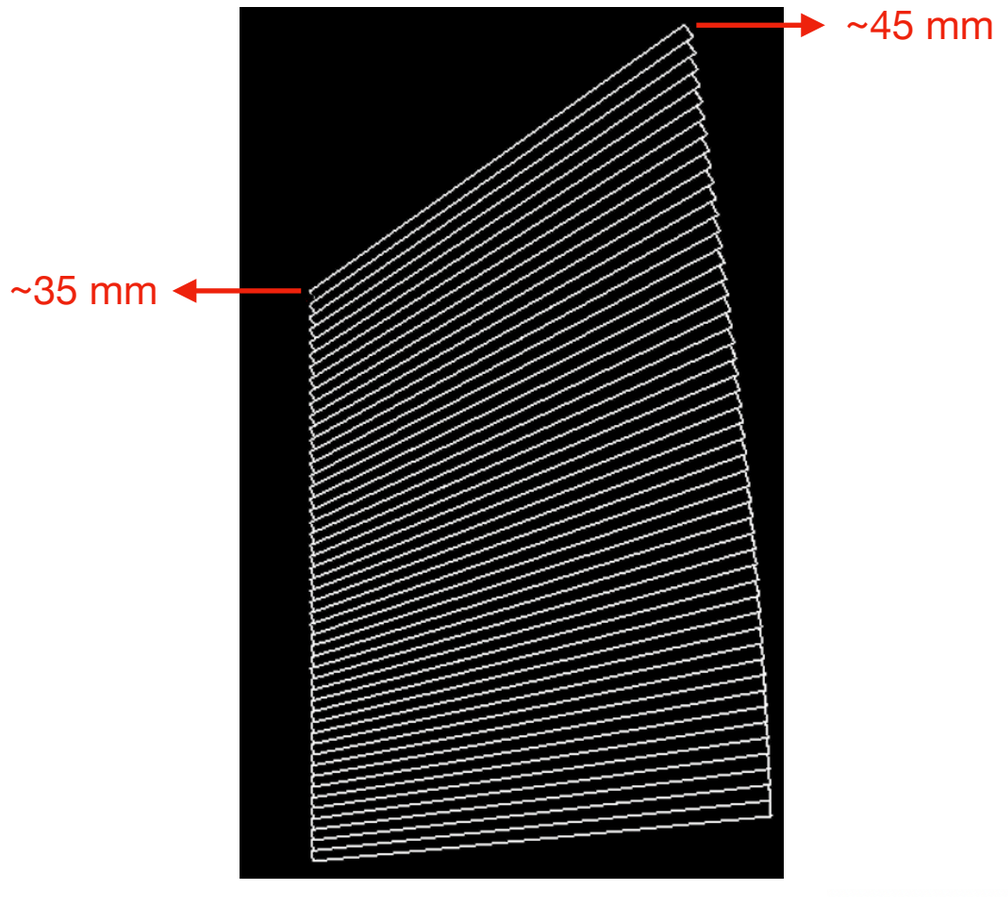
When we used copper, the bottom length of the tower was 40mm



With Tungsten, we can reduce It to 35mm by virtue of its smaller Moliere radius

Number of Endcap Tower(Eta direction) 40

Number of Endcap Tower(Eta direction) 50



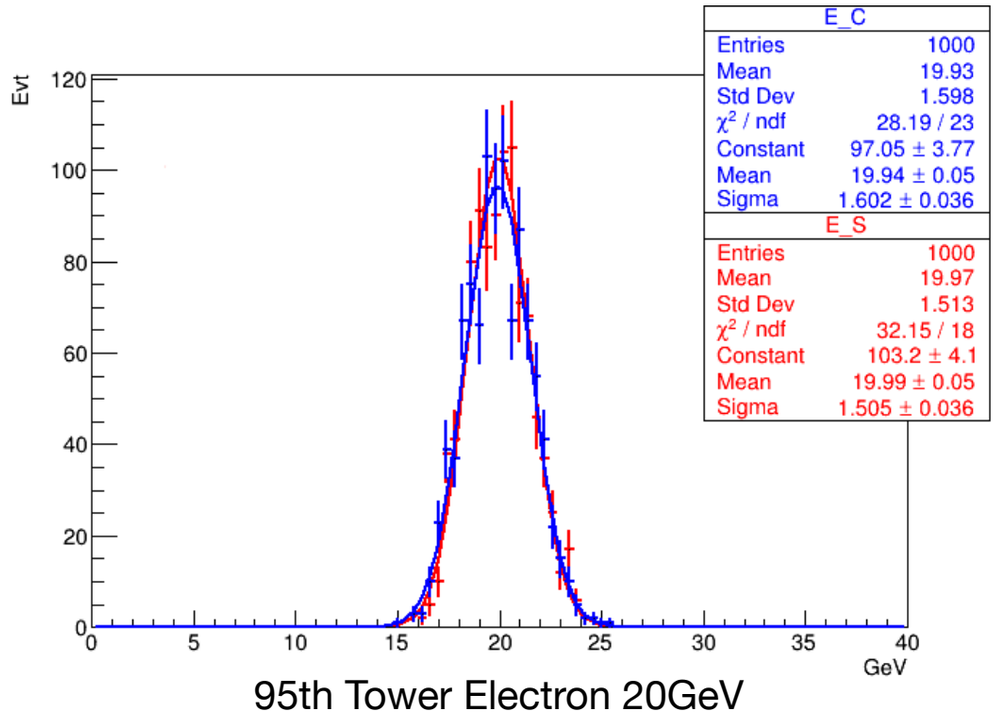
Moliere Radius

- Copper 15.2 mm
- Tungsten 9.3mm

Tungsten EM energy resolution

Measured 5 different energy of e- beams

5, 20, 50, 90, 110 GeV

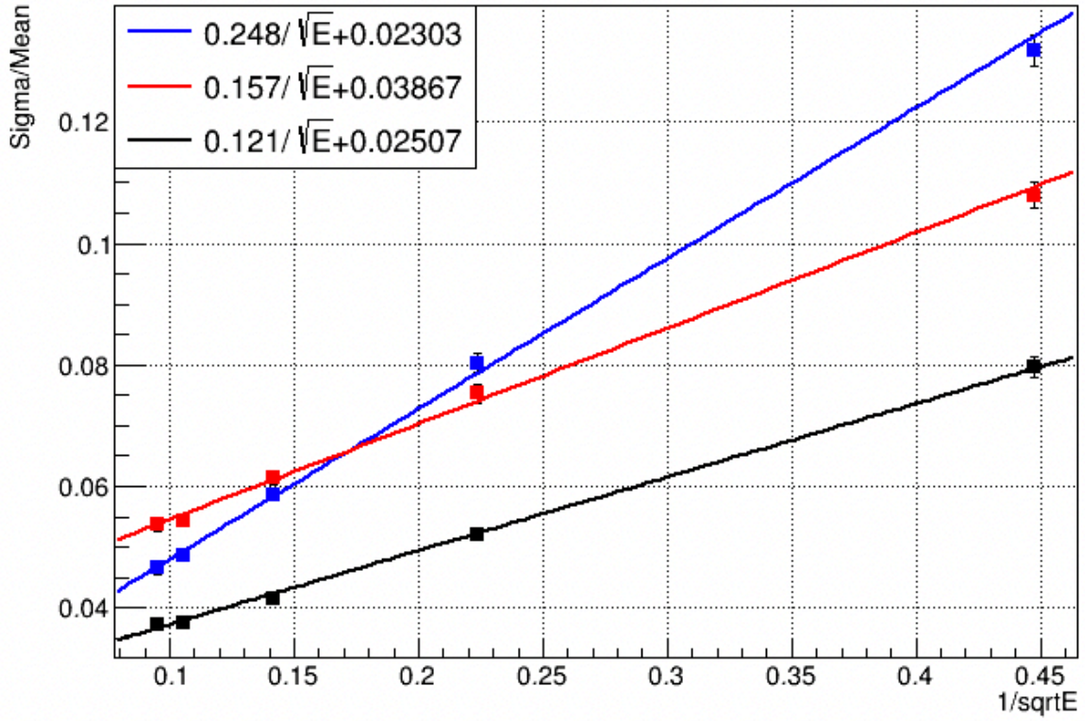


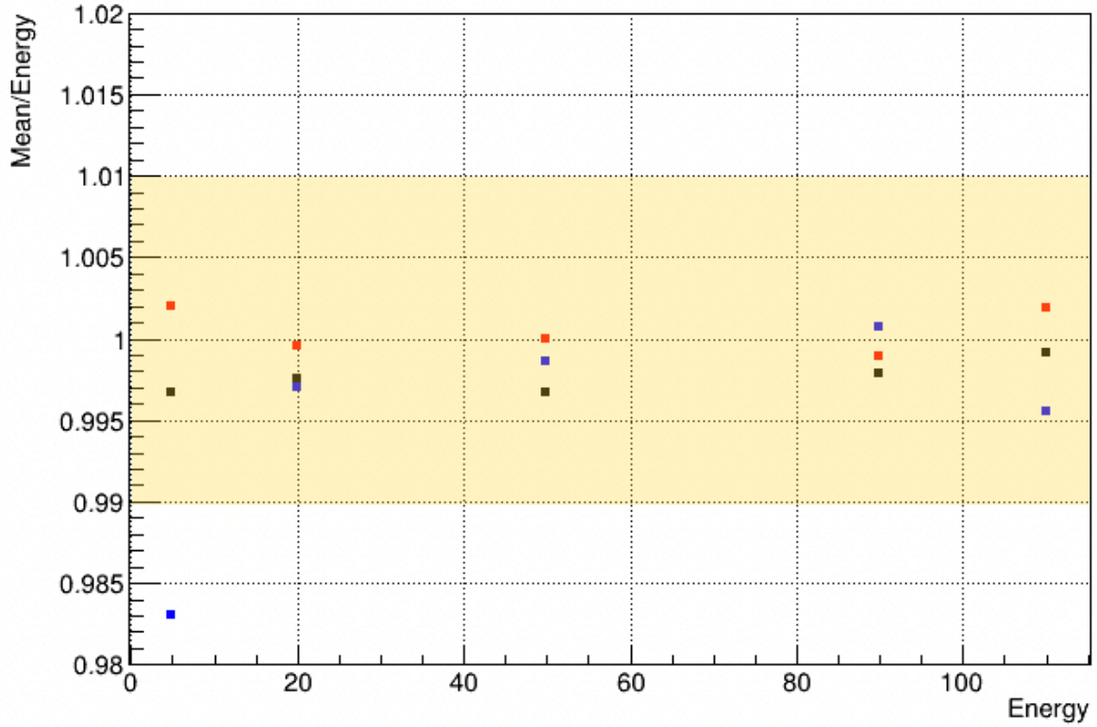
95th Tower Electron 20GeV

Cerenkov ch.

Scintillation ch.

Dual-readout corrected





Tungsten Hadronic energy resolution

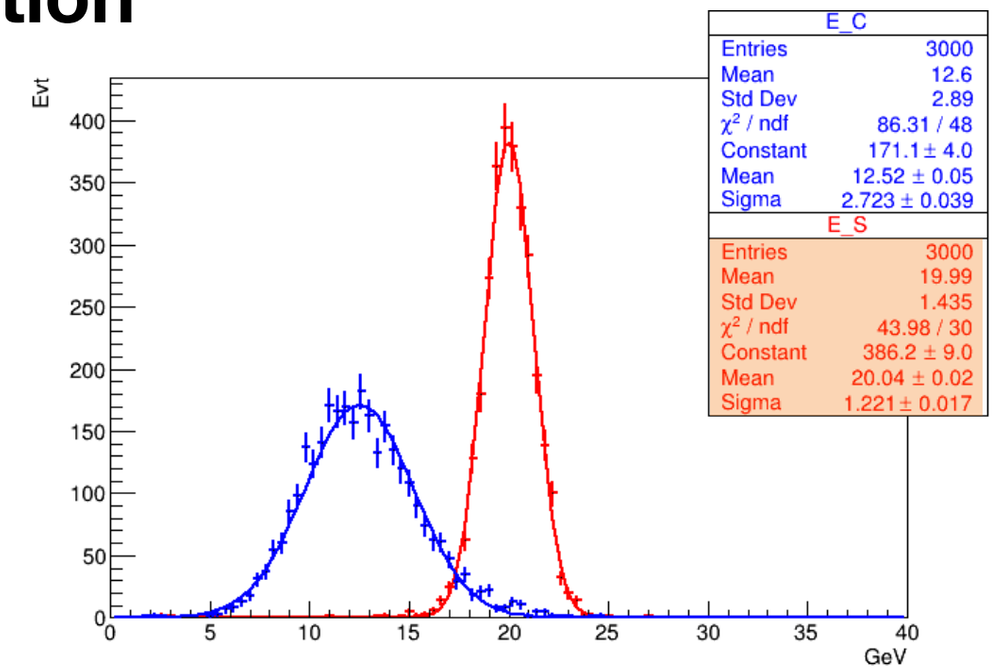
Calculated 5 different energy of pi+ beams

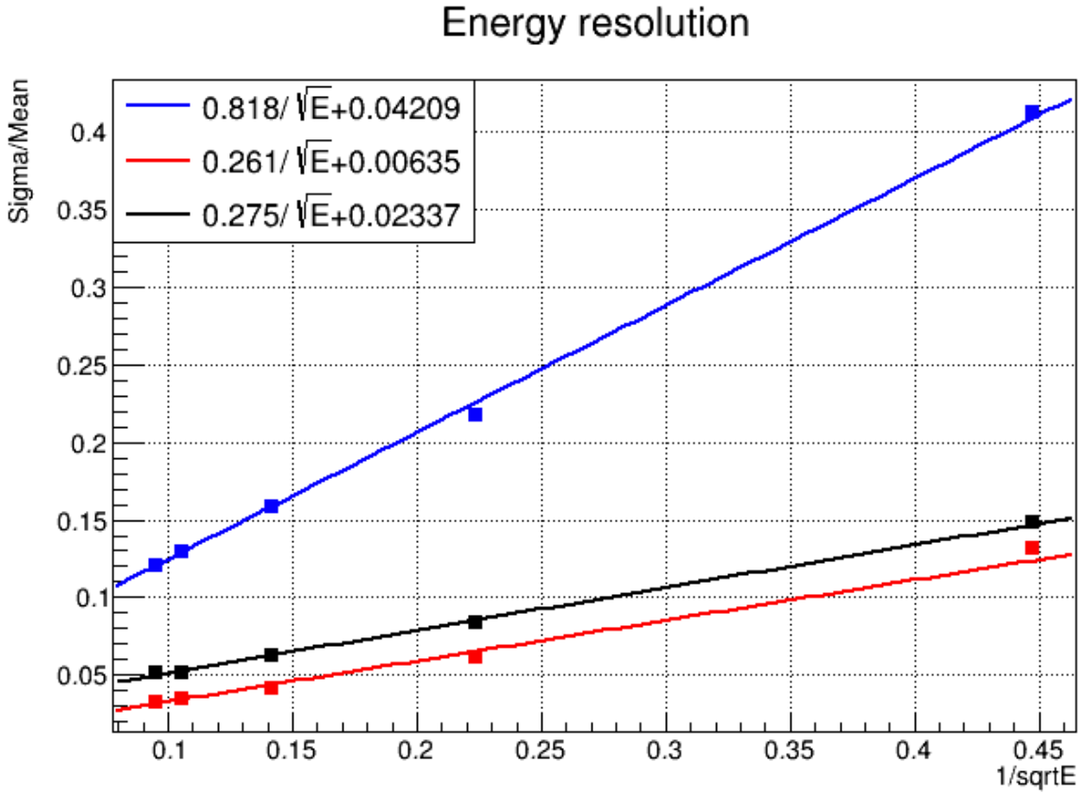
5, 20, 50, 90, 110 GeV

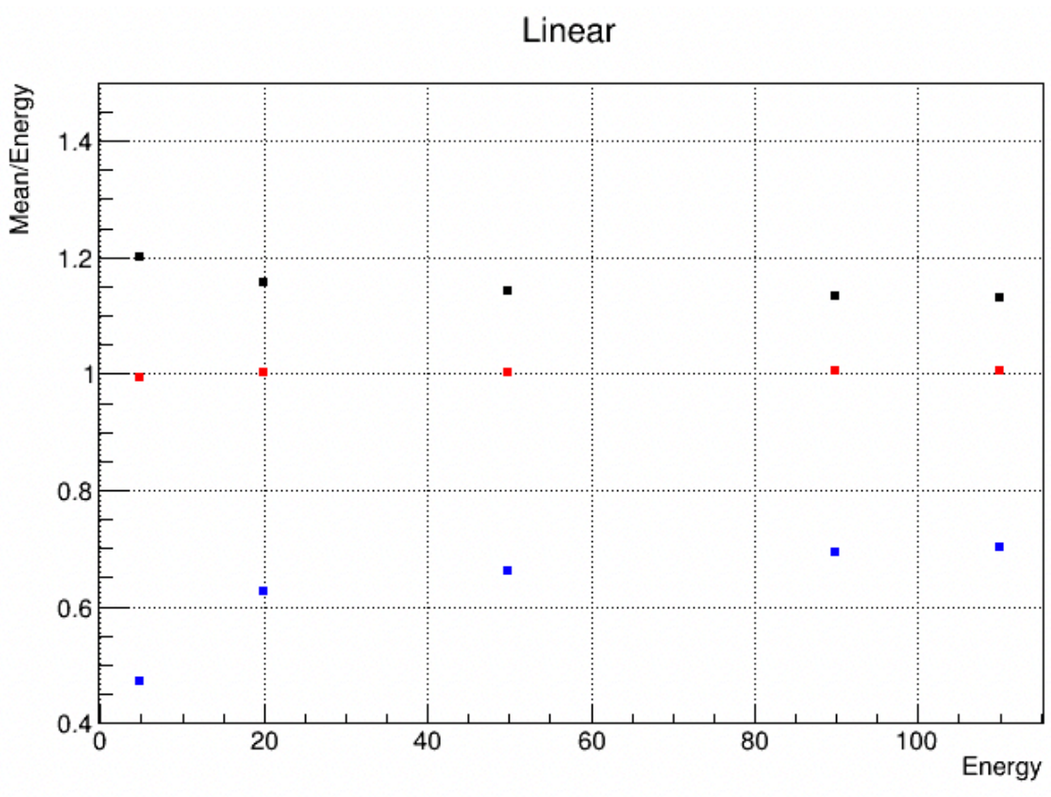
Leakage problem was largely resolved!

f_em can be measured as only scintillation channel

- Cerenkov ch.
- Scintillation ch.
- Dual-readout corrected

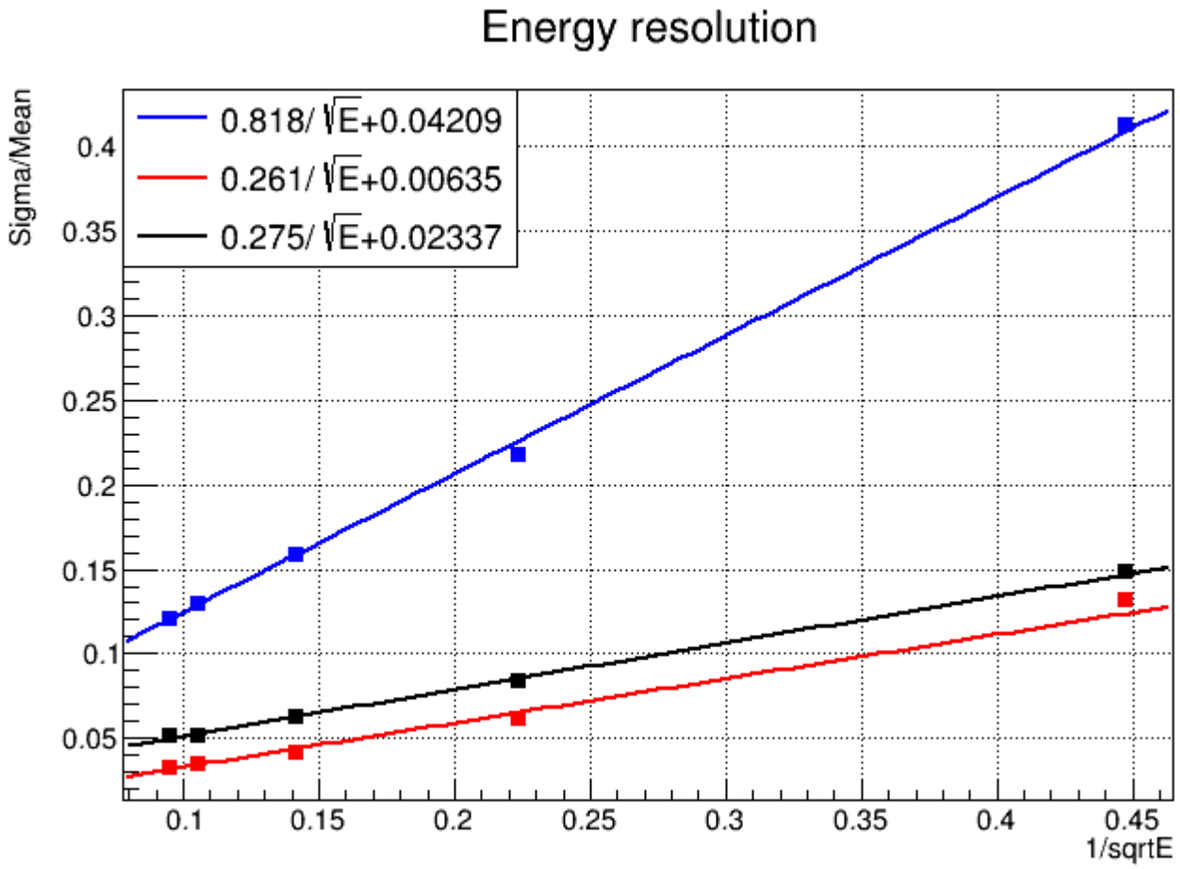




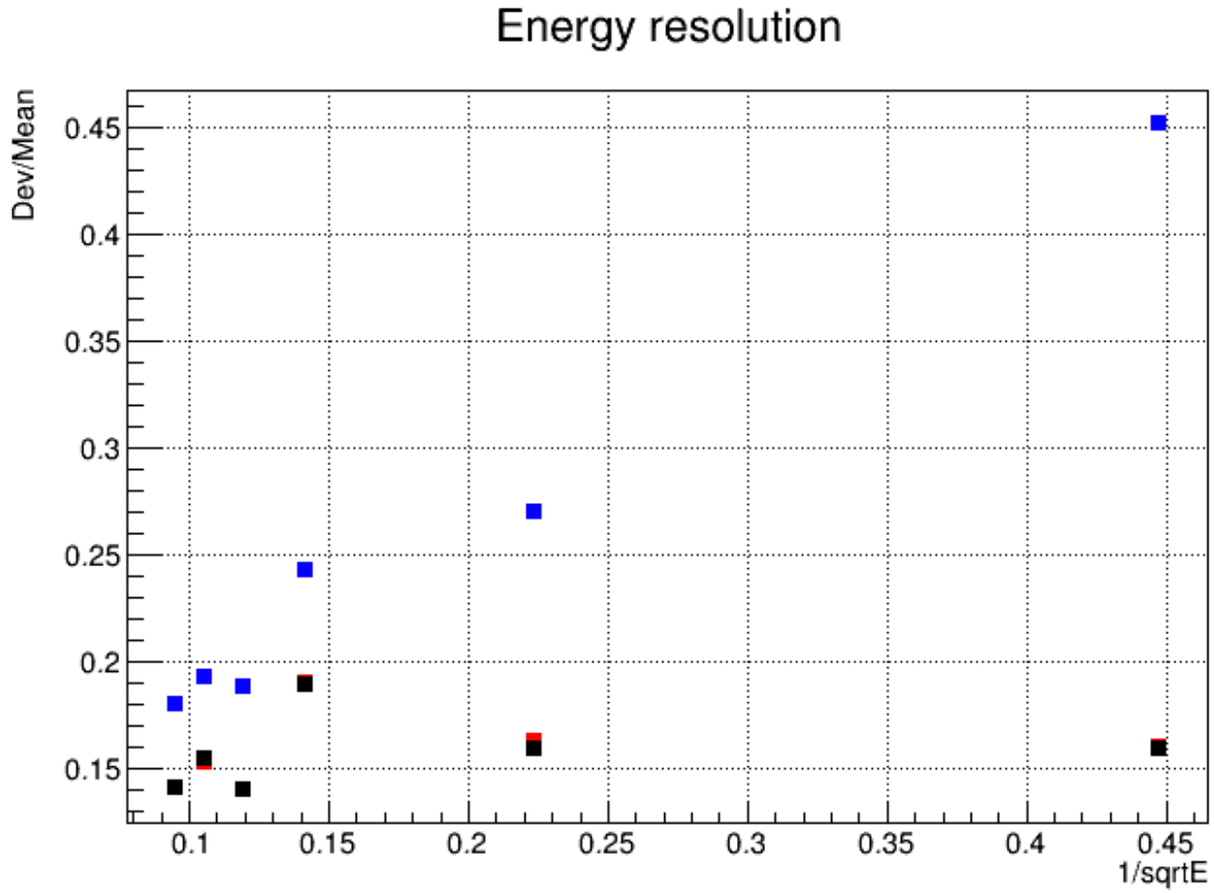


Tungsten Hadronic energy resolution

- Cerenkov ch.
- Scintillation ch.
- Dual-readout corrected



Tungsten (1.25 m)



Copper (1.25 m)

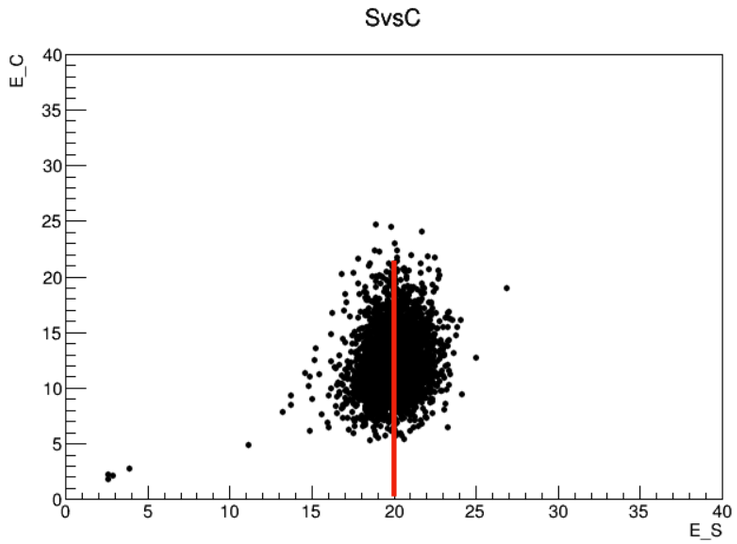
Tungsten Hadronic energy resolution

Calculated 5 different energy of pi+ beams

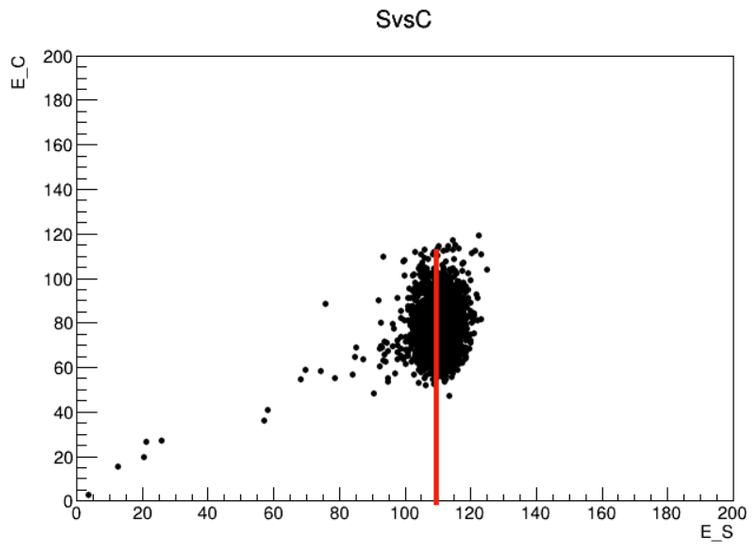
$$(\frac{h}{e})_s = 1$$

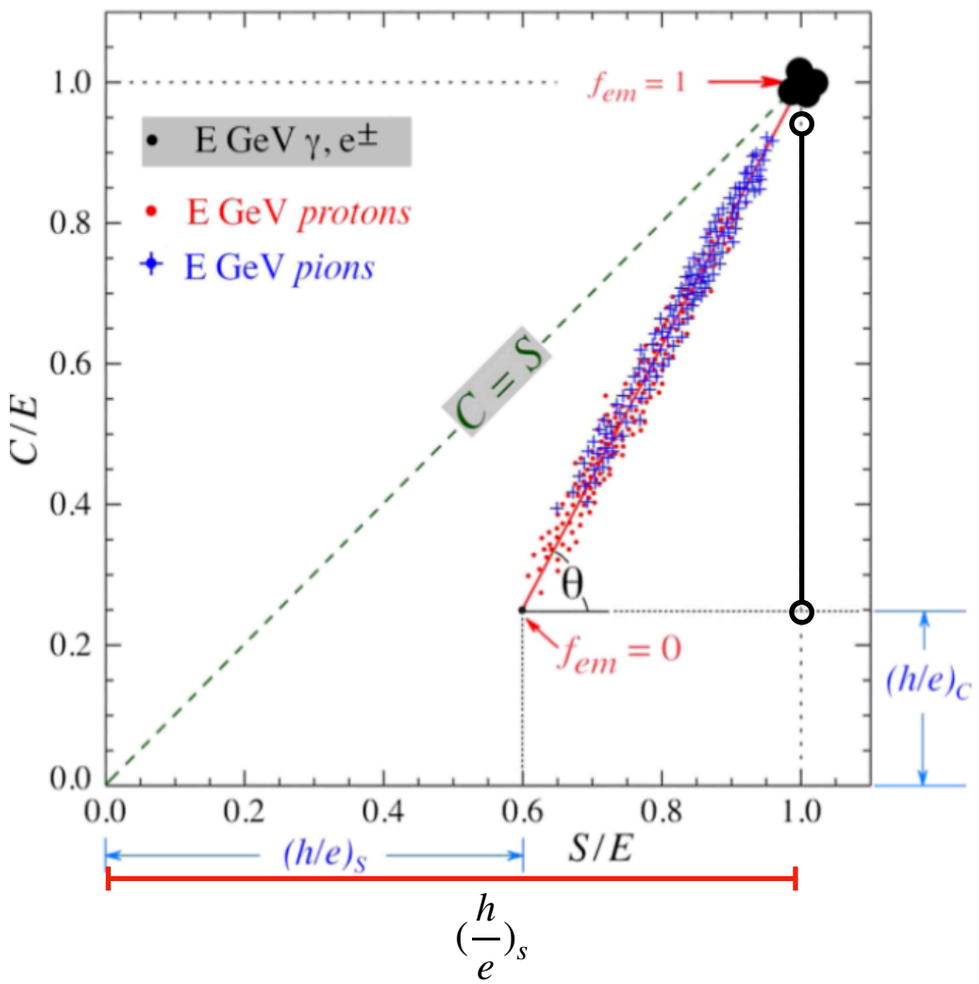
$$E = S$$

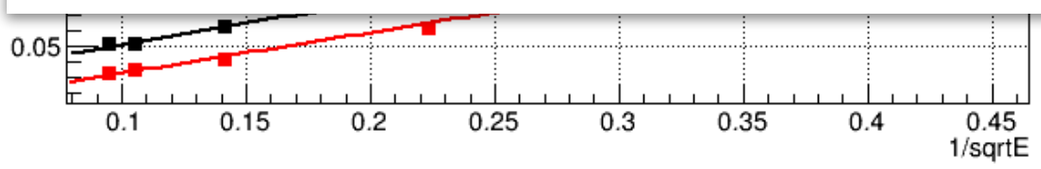
Pi+ 20GeV

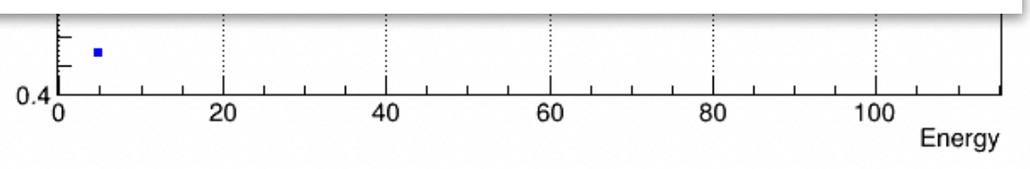


Pi+ 110GeV







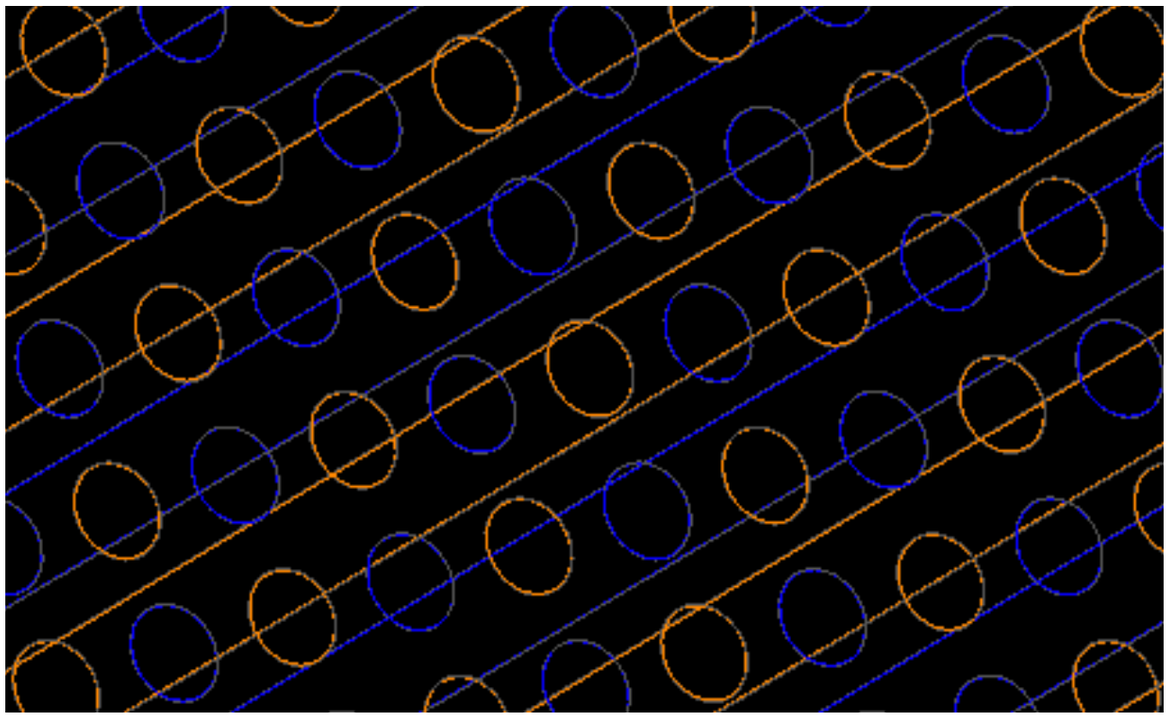


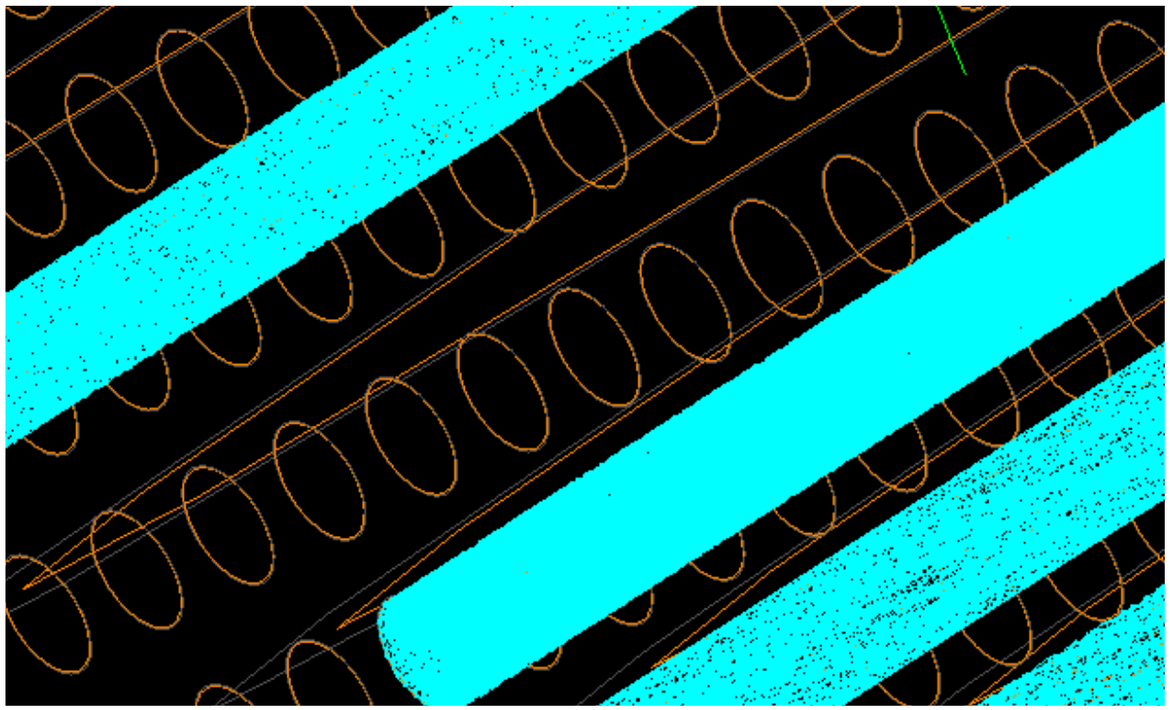
Tungsten with Scintillation fiber only

Cerenkov fibers is not needed at Tungsten

Implement only scintillation fiber

Without Cerenkov fiber





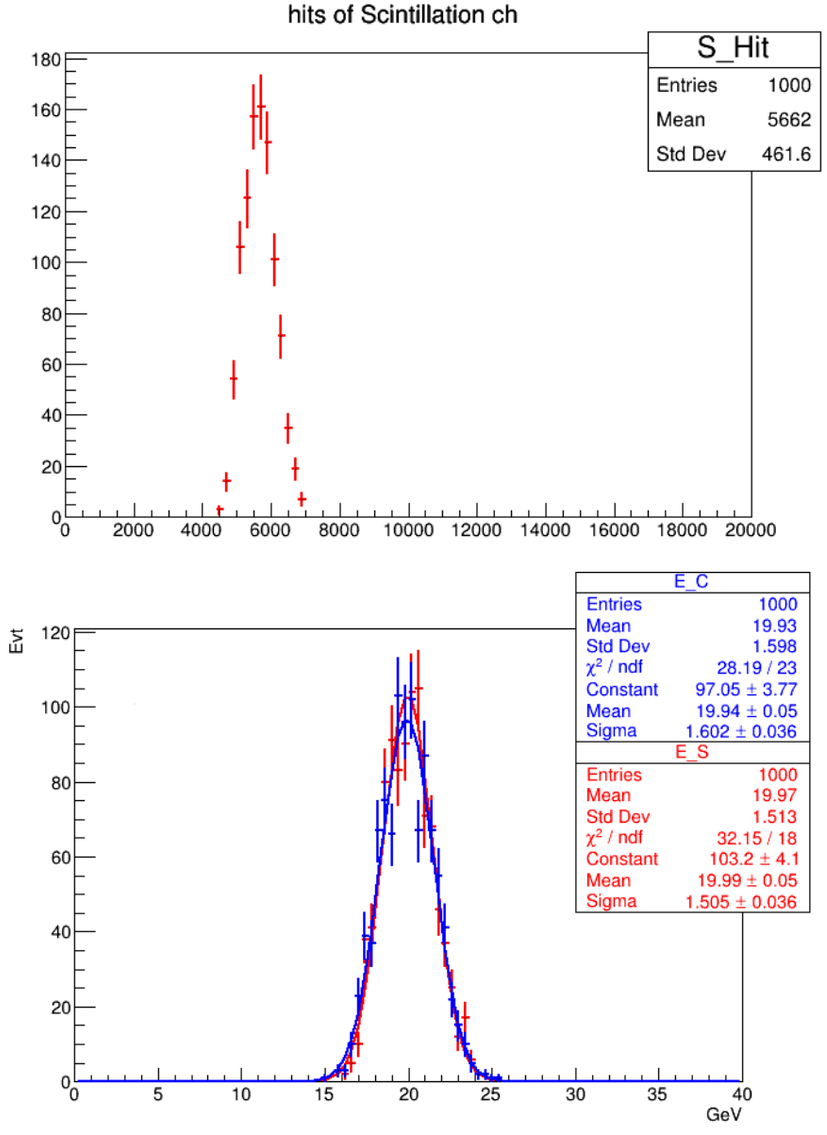
Calibration

Calibration with electron 20GeV

According to # of photo-electrons increase in scintillation channel

Can measure higher quality energy resolution

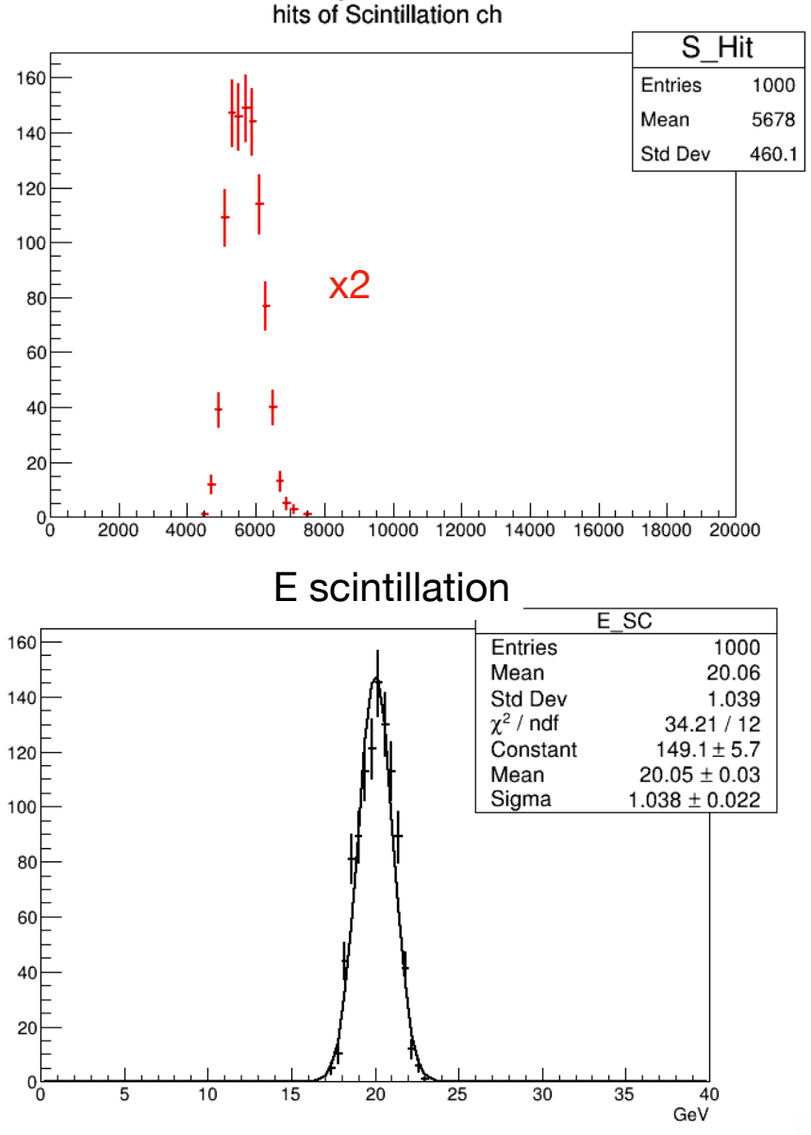
Dual-readout



Dual readout scint $\frac{1.505}{19.99} = 7\,\%$

Only scint $\frac{1.038}{20.05} = 5\,\%$

Compensation



E scintillation

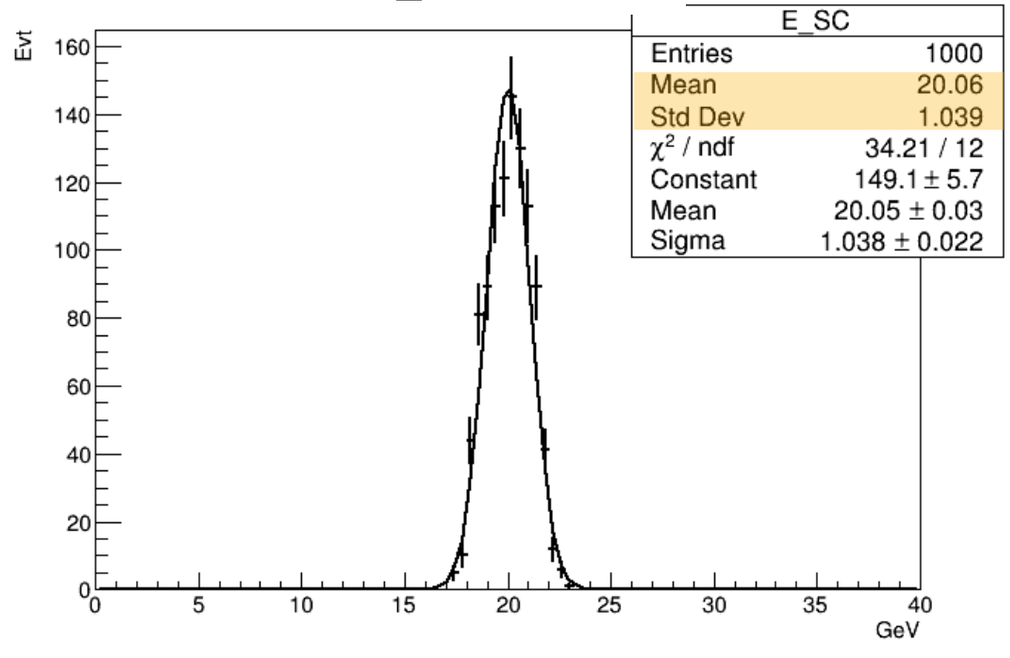
Only-scintillation EM energy resolution

Calculated 6 different energy of e- beams

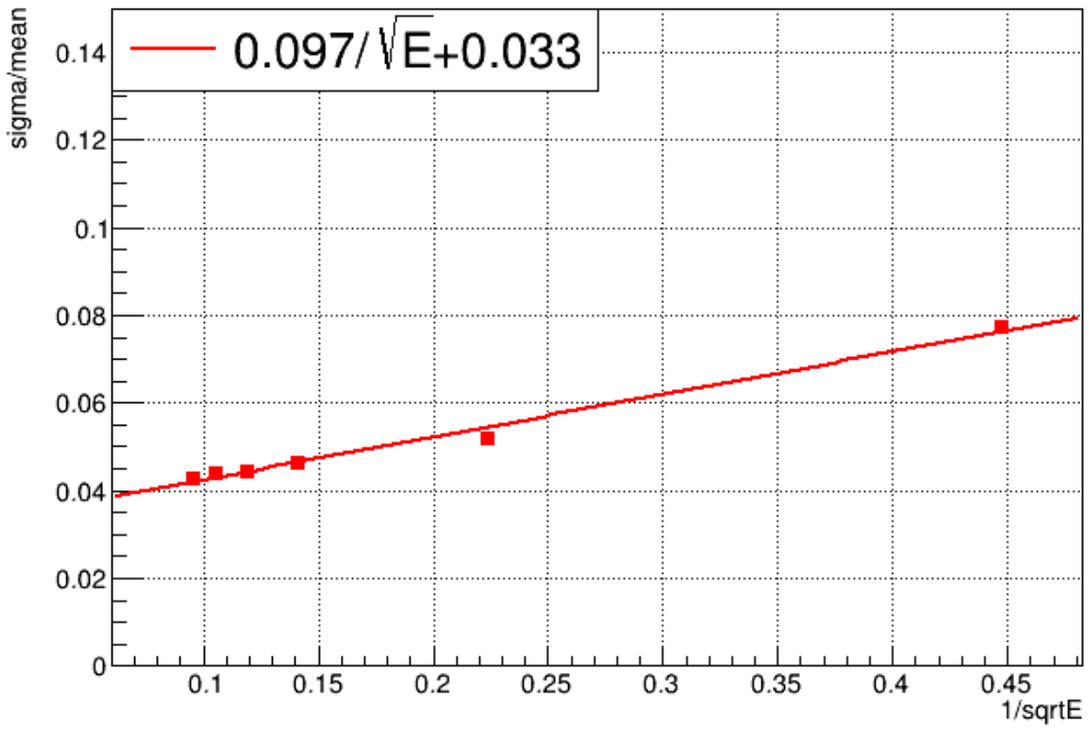
5, 20, 50, 70, 90, 110 GeV

This plots drew with Std.Dev of Mean value

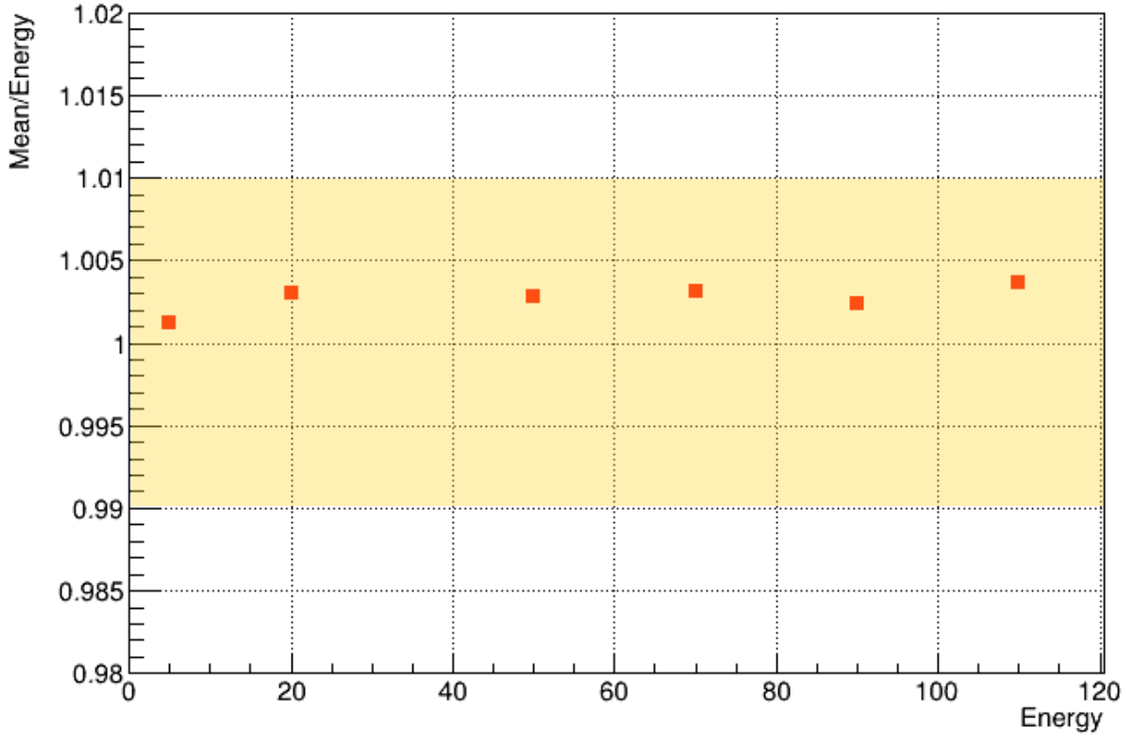
E_scintillation



Energy Resolution



Linear



Comparison Energy resolution

EM energy resolution

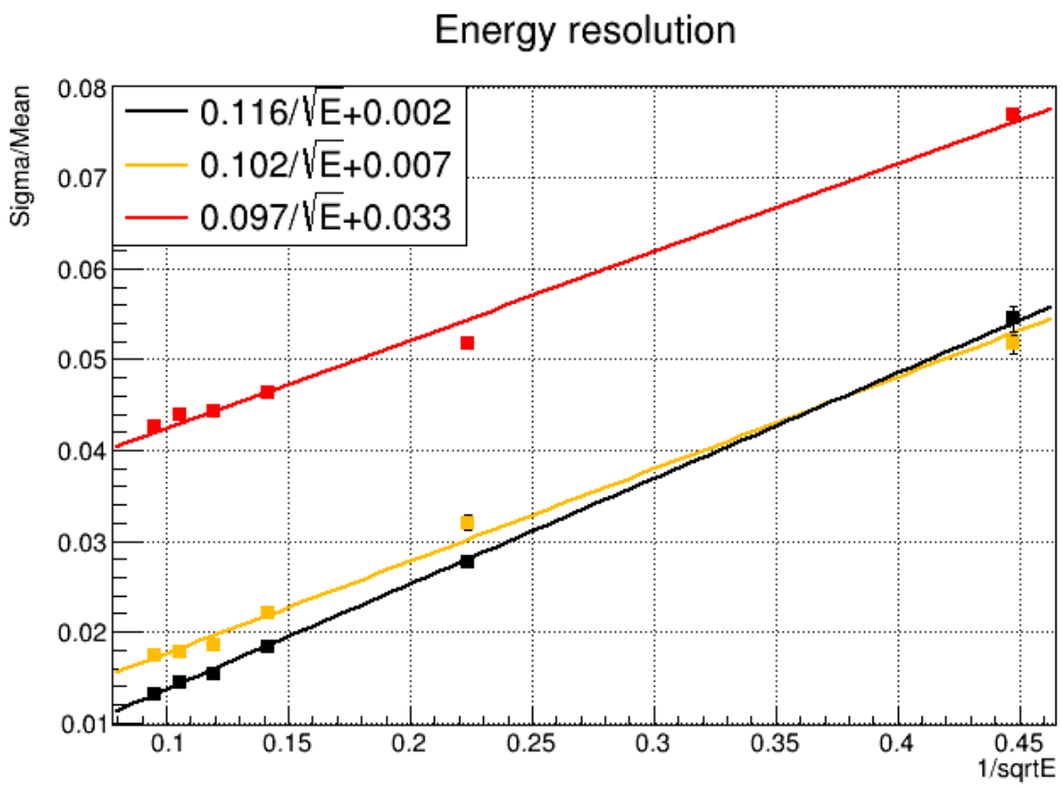
Calculated 6 different energy of e- beams

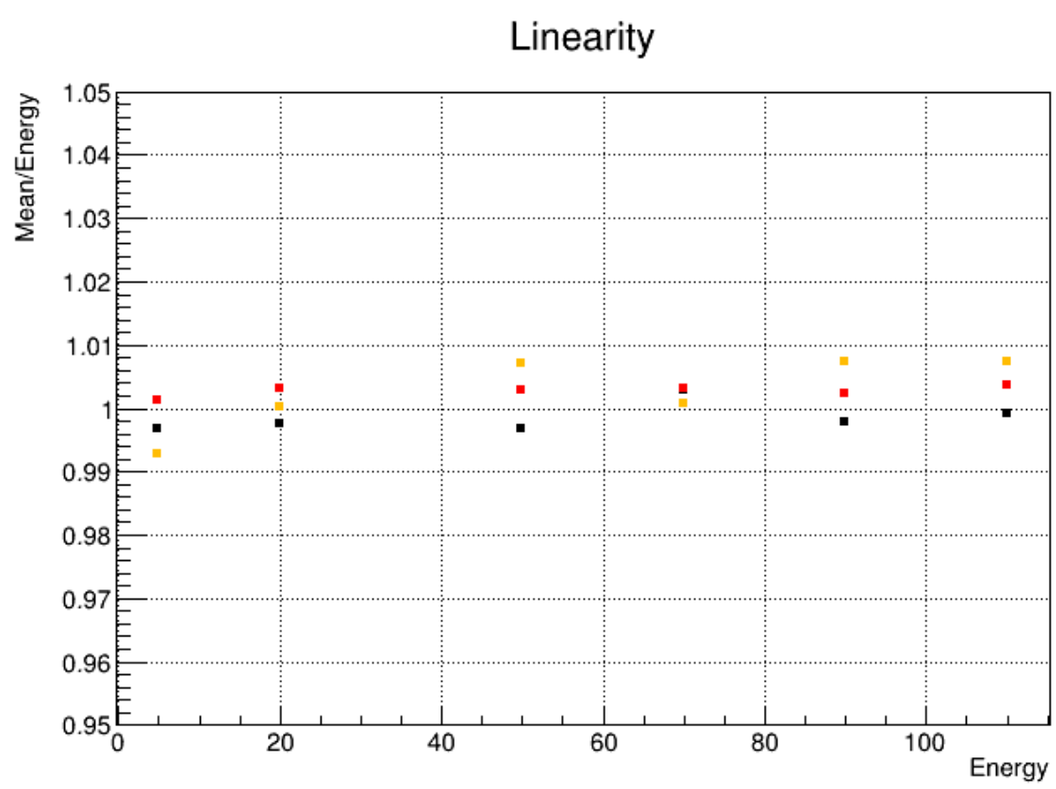
5, 20, 50, 70, 90, 110 GeV

2.5m Copper dual-readout calorimeter

1.25m Copper dual-readout calorimeter

1.25m Tungsten compensation calorimeter





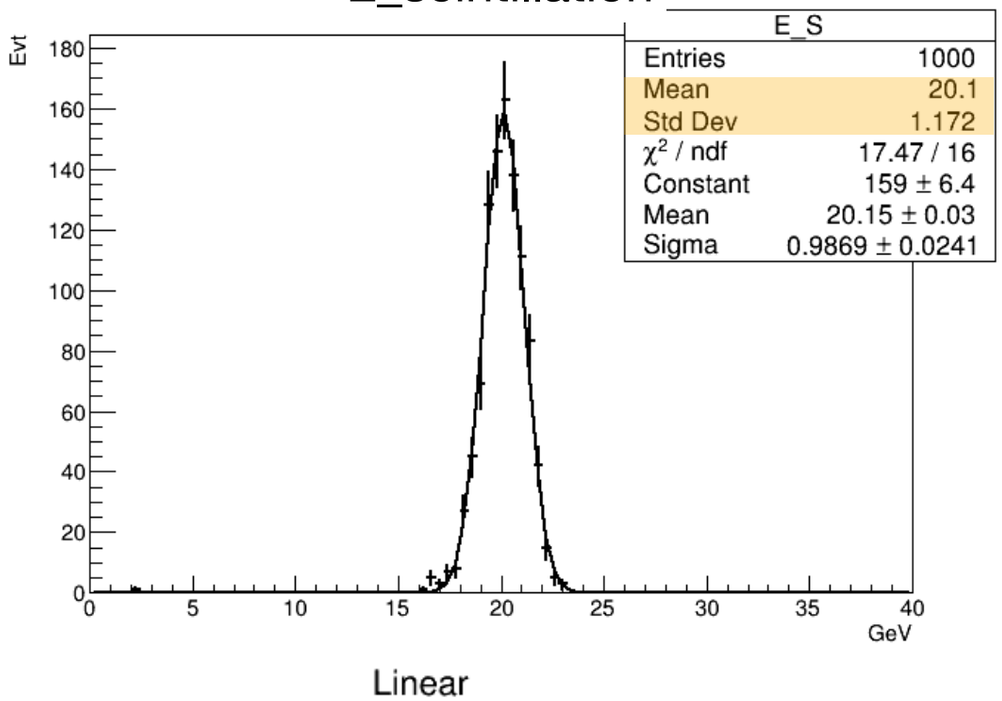
Only-scintillation

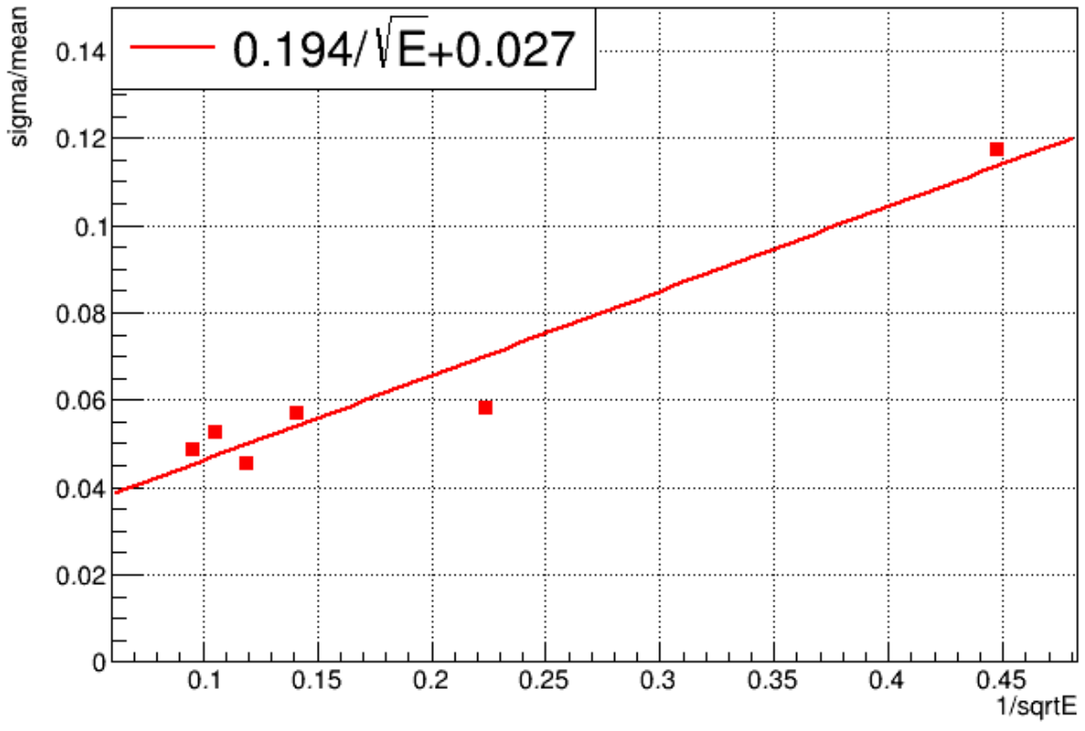
Hadronic energy resolution

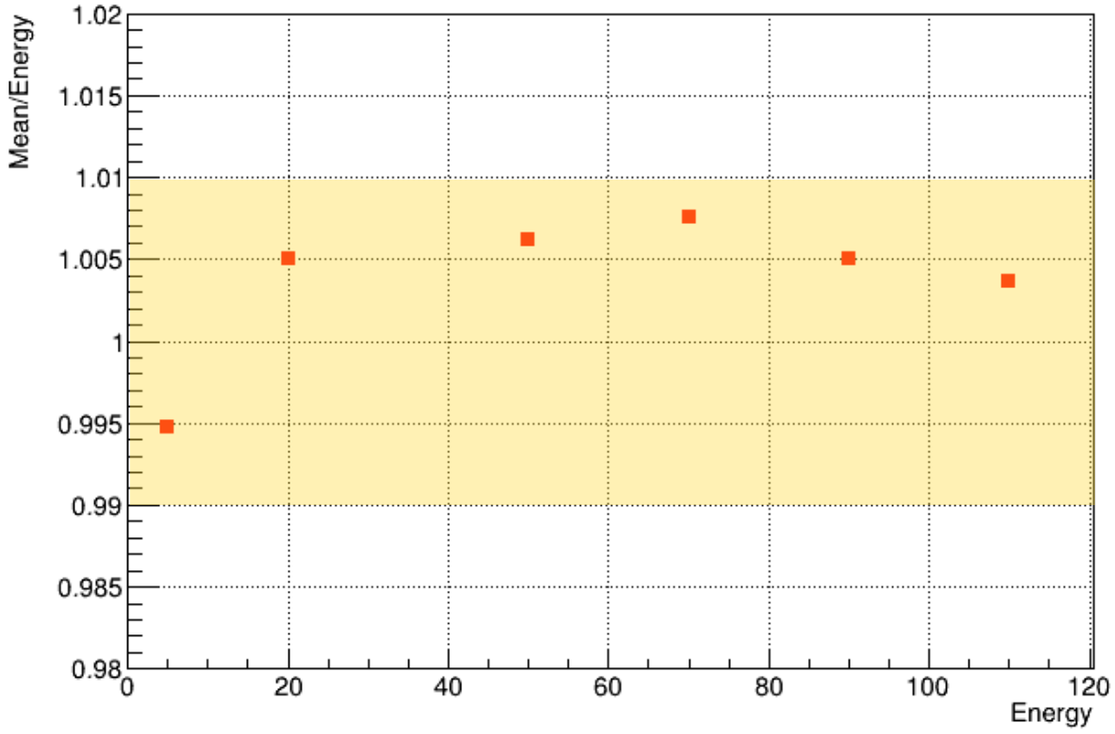
Calculated 6 different energy of pi+ beams

5, 20, 50, 70, 90, 110 GeV

This plots drew with Std.Dev of Mean value







Comparison Energy resolution

Hadronic energy resolution

Calculated 6 different energy of pi+ beams

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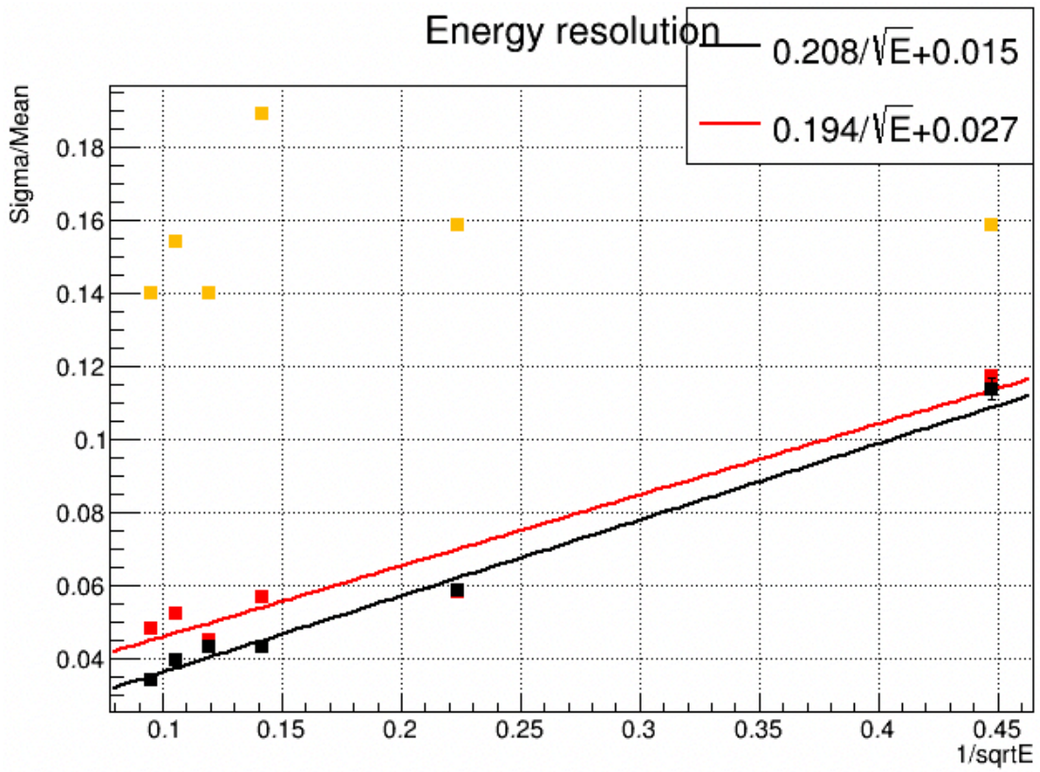
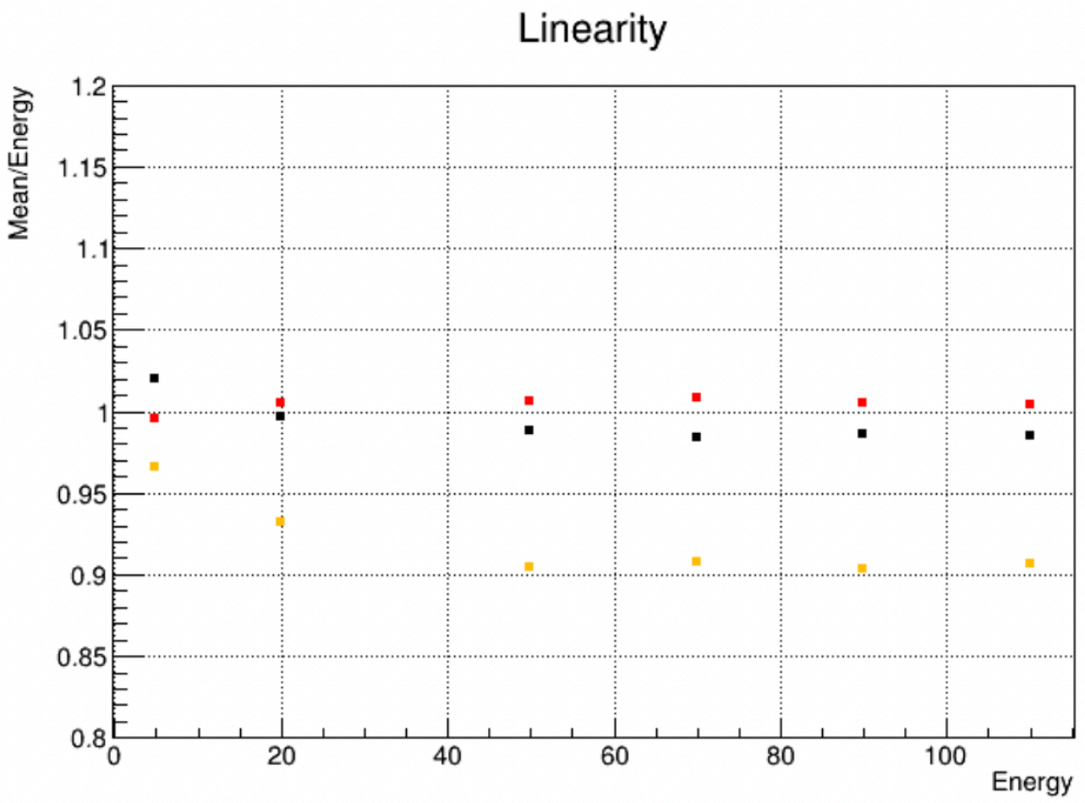
2.5m Copper dual-readout calorimeter

1.25m Copper dual-readout calorimeter

1.25m Tungsten compensation calorimeter





Summary

*** As the forward Hcal In ECCE forward, we can not use copper as the dual-readout calorimeter due to the punch-though**

*** One solution is to use Tungsten instead of copper, and we observed a large removal of the energy leak**

*** With Tungsten, the energy resolution for electron is worse, however the linearity for the hadronic particles are significantly improved**

Ex) 1.25m copper 110GeV Pi+ beams, leakage about 15%

*** And if we use Tungsten, use of two different channels are not necessarily**

*** The scintillation-only scheme is excellent in terms of energy resolution**

EM energy resolution

	Stochastic	Constant
Copper 2.5m	0.116	0.002
Copper 1.25m	0.101	0.007
Tungsten scint	0.097	0.033

Hadronic energy resolution

Stochastic	Constant
0.208	0.015
N/A	N/A
0.194	0.027